ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Vol. 6 JANUARY–MARCH, 1952 No. 1

Semi-Popular Articles

Technical Literature Review

Utilization Abstracts

Book Reviews

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Founded, managed, edited and published by

EDMUND H. FULLING

at

The New York Botanical Garden

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The Duboisias of Australia

These shrubs have prospects for replacing, or at least greatly supplementing, Atropa and Hyoscyamus as sources of hyoscine and hyoscyamine. The former drug has been much used in childbirth and psychiatry, the latter as the source of atropine for dilating pupils.

COLIN BARNARD

Division of Plant Industry, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia

Introduction

The leaves of the three species of the Australian genus *Duboisia* contain alkaloids of interest and value. *Duboisia myoporoides* and *D. Leichhardtii* have been found to contain hyoscine and hyoscyamine in high concentration, and since **1942** have been used in Australia for the commercial production of these alkaloids. Atropine is prepared from hyoscyamine; it dilates the pupil of the eye and is used primarily in ophthalmology. It was obtained previously from certain other solanaceous plants, particularly *Atropa Belladonna* and *Hyoscyamus* spp. Hyoscine was reclaimed from the mother liquors after hyoscyamine had been extracted from the same plants, and before the second world war was used mainly in association with morphine as an analgesic at childbirth and as an hypnotic agent in certain mental disorders. As the war progressed the demand for hyoscine increased, since it was found of great value in the treatment of bomb shock and also as a preventative of sea and air-sickness. *D. Hopwoodii*, the third species, contains, strangely enough, the unrelated tobacco alkaloids nicotine and nor-nicotine, and its leaves were used before the coming of white man as a chewing narcotic by the aborigines.

These three plants are of particular interest because they are endemic to Australia. With the exception of the hardwoods and the oils of the genus *Eucalytus* and other Myrtaceous plants, and the tanning barks of the acacias, the native flora of Australia has been rather unproductive of plants yielding materials and substances that man has been able to utilize for his sustenance and comfort. To the economic plants of European civilization the floras of Africa and Asia largely contributed, and many substantial additions came from the New World. The Australian flora, characterised as it is by a high degree of endemism, has by contrast been singularly disappointing in this respect. There are, for instance, no plants which produce fibres comparable with linen, cotton, jute, ramie or sisal, nor with any of the numerous species which yield second rate fibres of these types. There is but one native Australian plant which produces a product deemed edible by civilized man and would seem worthy of improvement and cultivation. This is *Macadamia ternifolia* which yields a very fine nut and which has to a limited extent been cultivated in the Hawaiian islands. The early voyagers to Australia returned with neither herbs and spices of the Orient nor the fresh food plants of the New World to add to European civilization. Its flora like its fauna, with marsupials and the platypus, was scientifically of great interest, utilitarianly of very little.

In the southeastern coastal areas, which were first colonized, myrtaceous plants and especially eucalypts with their fragrant oils were abundant. It was natural, therefore, that the first and prime interest of the early investigators in the chemistry of Australian native plants was in their essential oil content. The chemistry of eucalyptus and other myrtaceous oils was studied, and the product of these native plants became increasingly known and utilized.

In addition to essential oils many Australian plants contain substances of other chemical and pharmacological interest and possible value. Until recently, however, very little systematic investigation had been made in this field. Most attention had been paid to the identification of plants poisonous to stock, and there has been fragmentary study of a few particularly obvious and promising species. At the present time the Commonwealth Scientific and Industrial Research Organization, in conjunction with the Universities of Queensland, Sydney and Melbourne, is engaged upon a systematic survey of the chemistry of native plants and the pharmacology of substances derived from them. Utilization of the *Duboisia* species as sources of hyoscine and atropine was the first direct result of this work.

Botany and Distribution

Duboisia myoporoides is a tree with broad-lanceolate to obovate glabrous leaves three to four inches long, and may grow 45 feet tall, though rarely does it attain this size. The bark of the trunk is usually very corky, the wood extremely light. From these characters it obtained its local name of "corkwood tree". *D. myoporoides*, like the other two species, flowers profusely in spring; the blossoms are small, white and bell-shaped with occasional mauve streakings in the throat of the corolla, and are borne in cymose panicles. The fruit is a small black gobular berry about 3/16 inch in diameter.

This species occurs along the east coast of Australia from latitude 35° S. in the south to at least latitude 15° in the north. In the extreme south it is restricted to the coastal plain, but in the more northern district it extends back into the valleys of the Great Dividing Range. It is thus confined to the zone in which the rainfall exceeds a monthly mean of two inches for 11 months of the year and in which frosts rarely occur. It is found on various kinds of soil, but seems to prefer a rich basaltic type and creek banks. In its natural state it occurs as isolated trees on the edges of the forest. After the forest has been cleared, and especially after it has been burnt, thicker stands develop, for regeneration is more rapid than in most other species. When felled or burned it suckers profusely and is characteristically found in clumps which have originated in this manner. Though reported in the literature as occurring in the Philippine Islands, it is unlikely that this is so. It is found in New Caledonia and possibly occurs in New Guinea.

Duboisia Leichhardtii is much like *D. myoporoides* in general habit though not so leafy. Its leaves are smaller and narrower, and its flowers a little larger. It is developed only in Australia, and the area of distribution is limited to a small region in southeastern Australia in the vicinity of longitude 149–152° W., latitude 24–27° S., and the watershed of the Burnett River. It has been reported from Mt. Playfair and from the Grey Ranges (44) in New South Wales, and Bailey (1) stated that it was said to be common in the area of the Comet, Gilbert and Suttor Rivers in Queensland. There seems no doubt that the record of its occurrence in the Grey Ranges was wrong and that *D. Hopwoodii* was mistaken for this species. There have been no further records of its occurrence in

the Gilbert or Suttor river areas referred to by Bailey, and, so far as we know, it cannot now be found there. The specimen from Mt. Playfair seems to have been of a single chance or occasional occurrence. In the Nanango-Yarraman-Kingaroy area, where it is best developed, it is confined to the red soils. These soils are the best agricultural and pastoral land, and they have mostly been cleared and kept clear of timber. The species is now, therefore, almost confined to roadsides and occasional grazing paddocks which have not been scrubbed of recent years. Its distribution on the suitable soil type is sparse. A number of types intermediate in form between *D. myoporoides* and *D. Leichhardtii* are found, which are apparently hybrids between the two species.

Duboisia Hopwoodii is a small shrub seldom exceeding eight feet in height with narrow lanceolate leaves which are smaller than those of *D. Leichhardtii.* It grows scattered throughout the drier regions of Australia, mostly within the ten-inch rainfall zone but extending in certain areas into the zone in which the annual rainfall approaches 15 inches. It occurs in southwestern Queensland along the Mulligan and Georgina Rivers, in South Australia, in Central Australia and is probably most abundant in Western Australia. It generally inhabits sandy open country and is found as scattered individuals or in small groups

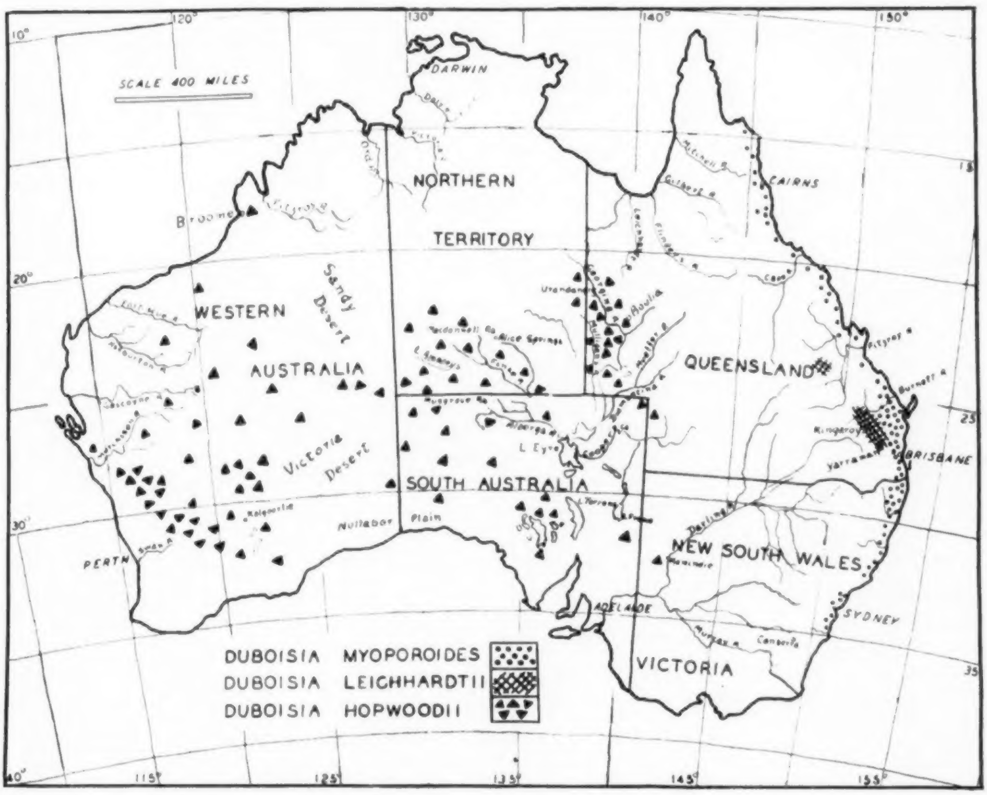

FIG. 1. Distribution of *Duboisia* in Australia. *D. myoporoides* is restricted to the eastern coastline; *D. Leichhardtii* to a small area in southeastern Queensland; and *D. Hopwoodii* is sparsely scattered over a wide area of the interior.

frequently associated with *Spinifex* (*Triodia*). In Western Australia, particularly between latitudes 28° and 32° S., it is more abundant and often grows in small thicket-like patches.

Early Botanical History

Robert Brown (13) first collected specimens of *Duboisia myoporoides* during 1802–05 whilst he was the naturalist to the Flinders Expedition and was examining the flora of Novae Hollandiae. He named the genus after the French botanist Dubois and described *myoporoides* in his Prodomus of 1810.

Being common in the coastal areas just north and south of Port Jackson, *Duboisia myoporoides* was collected and noted by a number of botanists during the first quarter of the 19th century. C. Fraser (17), the first Colonial Botanist and Superintendent of the Sydney Botanical Garden, collected it at Pt. Macquarie in 1816, and F. W. Sieber (59), a visiting Austrian botanist, in 1823.

White men first came in contact with *Duboisia Hopwoodii* by way of the preparation made of its leaves and twigs by the aborigines and known as "pituri". Wills (72), of the Burke and Wills exploring party, wrote in his diary under date of 7th May, 1861: "In the evening various members of the tribe came down with lumps of nardoo and handfuls of fish until we were positively unable to eat any more. They also gave us some stuff they call bedgery or pedgery; it has a highly intoxicating effect when chewed even in small quantities. It appears to be the dried stems and leaves of some shrub". Dr. Beckler (8), who was the medical officer and botanist attached to the Burke and Wills Expedition, was left with the bulk of the party at a base near the present town of Menindie on the Darling River. There he collected specimens of a native plant which Baron von Mueller (8) described as *Anthocercis Hopwoodii,* the specific name being given in honour of Mr. Hopwood of Echuca, who had been a sponsor of the Burke and Wills Expedition. The same plant was collected during the 1830's by James Drummond (16) in Western Australia. When the Giles (20) exploring expedition of 1872 brought back specimens with fruits from Mt. Liebig in Central Australia, Baron von Mueller (45) placed the species in the genus *Duboisia.* It was not until several years later (1877), when W. O. Hodgkinson (29) brought back samples of pituri from northwest Queensland, that Mueller was able to identify the native preparation as being derived from *D. Hopwoodii.*

Duboisia Leichhardtii was described by Baron von Mueller (46) in 1867 from specimens brought back by the explorer Ludwig Leichhardt, in whose honour the specific name was given. The specimen lacking fruit, von Mueller placed the species in the genus *Anthocercis* at first. Ten years later (1877), after fruiting specimens had been found, it was transferred to *Duboisia* (47).

Early Knowledge of Chemistry and Pharmacology (to 1882)

We have noted that Wills came in contact with the native pituri in 1861. In 1872 Dr. Joseph Bancroft (2) of Brisbane, the first man to investigate the pharmacological properties of native plants in more than a dilettante fashion, obtained some pituri from a Mr. Gilmore who procured it from the vicinity of Eyre's Creek near Bedourie in southwest Queensland. Dr. Brancroft made infusions which he tested on animals and found toxic to the cat, dog, rat and frog. Dr. G. Bennett (10) of Sydney also contributed some notes on the drug in the New South Wales Medical Gazette in 1873. In 1877 Dr. Bancroft (3) obtained a further supply of pituri from W. O. Hodgkinson who made explorations in the north and west of Queens-

FIG. 2. A portion of an experimental plot of *Duboisia myoporoides* twelve months after planting at Nambour, Queensland. At this age the plants are thick leafy shrubs.

land. From this material Baron von Mueller was able to identify pituri as being the broken up leaves and twigs of *Duboisia Hopwoodii.*

The discovery that pituri originated from *Duboisia Hopwoodii* prompted him to investigate also the physiological action of watery extracts of the leaves of the other species, *D. myoporoides,* which the Rev. Woolls [1] had earlier commented upon. After injecting small amounts of these watery extracts into domestic animals he observed that "the pupil of the eye was always widely expanded, that the animals walked as if blind and if let alone fell asleep". He then tried the effect of dropping the extract into the eye of animals and also into the human eye. Again dilation of the pupil occurred. Bancroft sent some of his aqueous extracts to ophthalmic practitioners in Brisbane, Ipswich and Sydney hospitals. By them his observations were confirmed and the mydriatic properties studied in the human eye. Later Bancroft used *Duboisia* regularly instead of atropine in his own practice. Staiger (**62**), the Queensland Government analyst, prepared the active principle of *D. myoporoides* for Bancroft in **1877**. He found it to be a yellow oily-looking substance which refused to crystallize either alone or with acids, and was not volatile at 212° F.

In **1878** Dr. Bancroft visited England and took with him samples of both pituri and *D. myoporoides,* which he distributed for further investigation to a number of chemists and medical men. During **1878** and **1879** reports of their results were published. A new principle named "pituria" by some was recognised in the pituri with properties comparable with nicotine. Monsieur Petit (**51**) of Paris seems to have been the only one of these investigators who concluded that the alkaloid present was identical with nicotine. Gerrard (**18**) and Paul (**50**) and Drs. Tweedie, Ringer (**69**) and Murrell (**53**) as well as Wells (**70**) and Monsieur Petit (**51**) all came to the conclusion that the physiological action of the active principle in the leaf of *Duboisia myoporoides* was like that of atropine, but not quite the same. In **1880** A. W. Gerrard (**19**) announced to the Pharmaceutical Society of London that he had succeeded in preparing crystalline "duboisine", whilst A. Ladenberg (**34**) found that in composition and in analytical and physical characters the alkaloid which he obtained from *D. myoporoides* was identical with hyoscyamine. From this date until recently different investigators obtained varying and conflicting results. These are briefly reviewed later.

During this period, **1877–79**, when there was so much interest in the new principles found in the two species of *Duboisia,* further knowledge was obtained also in the use of the latter by the aborigines. Dr. McMillan (**49**) exhibited a sample obtained from the Diamantina-Coopers Creek area to the Australian Medical Society in **1876**. He said it was highly prized by the natives who smoked it. This statement would seem to be an error, and Dr. McMillan probably meant chewed, not smoked. There seems to be good evidence for believing that the aborigines acquired the

[1] The earliest reference to physiological activity in *D. myoporoides* was made in **1867** by the Rev. W. Woolls (**74**), a clergyman in the Richmond parish near Sydney, who was a keen amateur botanist and collected for Baron von Mueller. He recorded the observation that *Duboisia myoporoides* was used by the aborigines on account of its toxicant properties, and he said "they make holes in the trunks and put some fluid in them which when drunk on the following morning produces stupor" and also "that branches of this tree are thrown into pools for the purpose of intoxicating the eels and bringing them to the surface". Woolls says he had this information from a Miss Atkinson who in turn had it from the blacks. It is very doubtful, however, that this report was correct and that the natives ever did use *myoporoides* for these purposes.

habit of smoking a narcotic from the white man. Hodgkinson, whom we have mentioned above as providing Bancroft with his material of pituri, wrote in 1877: "The natives tell of mysterious legends of a place called Peecheringa, the natives of which area carry on an extensive commerce in a narcotic they call pecherie". He was then in the Mulligan River district in western Queensland. Dr. J. P. Murray (48), who was the surgeon to the party sent out under Howitt to rescue Burke and Wills in 1862, writing in the Lancet of January, 1878, recalled that King, who lived for several months with a tribe of natives in Coopers Creek after the death of the other members of the Burke and Wills Expedition, obtained a chew of pituri when his food became scarce and bad, and that this caused him to forget his hunger and the miseries of his position. In 1880 Professor Liversidge (39), then Professor of Chemistry at the University of Sydney, obtained some pituri from the blacks on the Barcoo (or Cooper) River, who, he said, obtained it from the Diamantina blacks who in turn traded yearly with the Mulligan tribe in whose country the pituri grew. His informant, a Mr. Wilson, told him that "the blacks mix the pituri with the ashes of the leaves of a particular plant and usually roll the mixture up with a green leaf into the form of a quill before chewing; the addition of the wood ashes is doubtless made for the same reason that lime is mixed with betel by the Malays and others, namely for the purpose of slowly liberating the alkaloid during the process of mastication. The quid or bolus is on ceremonial occasions said to be

FIG. 3. A single well-grown specimen of *Duboisia Hopwoodii*, some 200 miles northwest of Kalgoorlie, Western Australia.

passed from native to native each one masticating it for a time and then passing it on, it finding a resting place behind the original proprietor's ear until again required. The effects of the pituri seems from all accounts to be very much the same as that set up by tobacco smoking; it does not appear to have the exciting effect upon the blacks with which it was at one time credited. As is the case with other luxuries, it is reserved for the older men for their use exclusively, neither women nor young men being allowed to use it. The reasons for using it appear to be much the same as those which induce white people to smoke and in certain cases chew tobacco ".

In 1882 Baron von Mueller and H. Kempe (31) reported the use of *Duboisia Hopwoodii* by the natives in the vicinity of Alice Springs in Central Australia, for poisoning water holes to stupify emus and thus render them easy prey. Subsequent reports confirmed this usage which also included marsupials.

Thus by 1882 a fairly clear picture seems to have been obtained of the use of this plant by the natives as a narcotic, and the very interesting fact had been learned that an extensive trade existed between tribes on the basis of the drug. Other reports attributed different reactions to the drug, some saying that men took pituri before going on long journeys, as it increased endurance and reduced fatigue. The author tried chewing the material only once. It tasted very much like manure, and considerable willpower was necessary to commence chewing. After about an hour a slight exhilarating and intoxicating response was obtained which lasted for some hours. The occurrence of a very acute stomach pain, though fortunately of short duration, during the night following may have been unrelated. The experiment was not repeated.

Later History (1882–1940)

D. myoporoides. As previously mentioned, Gerrard in 1880 claimed to have produced crystalline duboisine from the leaf of *D. myoporoides,* and Ladenburg asserted that this alkaloid was identical with hyoscyamine. In 1885 Bender (9) obtained samples of leaves of *D. myoporoides* from two sources and obtained hyoscyamine in one sample, scopolamine in the other. In the meantime Professor Harnack (21) disagreed with Ladenburg's result that duboisine and hyoscyamine were identical on the grounds that the pharmacological activity of duboisine was much greater than that of hyoscyamine. So in 1887 Ladenburg (32, 33) procured some duboisine from Merck and investigated the matter further. He found that this sample consisted of hyoscine, hyoscine being an alkaloid which he had obtained and named from henbane (*Hyoscyamus niger*) in 1880. Schmidt (57) also identified scopolamine in the leaves of *D. myoporoides* in 1888 and showed that Ladenburg's hyoscine was identical with scopolamine. Then in 1890 Messrs. Schering & Co. (56) obtained both hyoscyamine and hyoscine in a sample of leaf of the same species. There seemed to be no doubt that samples of the leaf sometimes contained hyoscyamine, sometimes hyoscine and sometimes both alkaloids. Lauterer (36) reported in 1895 that hyoscyamine was contained in the older tissues, scopolamine in the younger leaves, and at this the matter remained in uncertainty until Mr. H. Finnemore and the author (6) studied the problem in 1940. During the intervening period, however, *D. myoporoides* was the subject of some investigation, and the occurrence of other alkaloids was recorded. In 1912 Carr and Reynolds (14) found that nor-hyoscyamine was present in a sample in addition to hyoscyamine and that this was probably the same as a substance which

Merck (42) had described in 1893 from *D. myoporoides* as pseudo-hyoscyamine. W. F. Martin of Messrs. T. H. Smith Ltd., Edinburgh, and Professors Mitchell and Barger of the University of Edinburgh in three papers (4, 5, 41) published from 1937 to 1940 described the examination of leaf of *D. myoporoides* collected in various districts and at different seasons. They found considerable variation in the total alkaloid content, but in no case was hyoscyamine isolated. They isolated and described four new alkaloids which they characterised and named "tigloidine", "valeroidine", "poroidine" and "isoporoidine".

FIG. 4. Inflorescence of *Duboisia myoporoides,* approx. $\frac{1}{3}$ natural size. The flowers are white or white tinged with violet.

Duboisia Leichhardtii. J. Lauterer (36) recorded in 1895 that the leaves of *D. Leichhardtii* contained chiefly scopolamine. He may or may not have had properly identified material. It was not until 1917, however, that this species was really investigated for the first time, which is very curious because of the great interest which the other two species aroused so many years before. Actually Bailey (1), the Queensland botanist, writing in 1880 that " it would be well if some person living in the parts where our endemic species *D. Leichhardtii* grows were to forward a quantity down to Dr. Bancroft . . .". In 1917 J. M. Petrie (52) found the total alkaloid content of the leaf to be 1.4% on a dry weight leaf basis, consisting of a mixture of nor-hyoscyamine, *l*-hyoscyamine and *l*-scopolamine with small amounts of atropine and nor-atropine.

Nothing more was done until recently (1940), and these recent developments are described in the next section.

Duboisia Hopwoodii. During the same period information was continuing to accumulate regarding the distribution of *D. Hopwoodii* and the use of pituri by the aborigines. C. Lumholtz (40) further reported on its occurrence and use in the southwestern Queensland area in 1890, L. Schultze (58) in the Finke River area in 1891, and Lindsay (38), the leader of the Elder Exploring Expedition in 1893, and Helms (38), the anthropologist of that expedition in 1895, reported its occurrence in northwest South Australia and the Great Western desert of Western Australia. In 1896 Winnecke (73), the leader of the Horn Scientific Expedition to Central Australia, and E. C. Stirling (63), the anthropologist of that expedition, described the occurrence and usage in the area of Lake Amadeus. In 1897 E. W. Roth gave the most detailed description of the occurrence of *D. Hopwoodii* and its use as a narcotic by the natives in the western Queensland area. In 1912 Spencer and Gillen (61) gave further reliable information about the Lake Amadeus region.

From all this information it became apparent that *D. Hopwoodii* was not universally used by the aborigines as a narcotic at all and that quite frequently reference to pituri had been not to a pituri made from *Duboisia Hopwoodii* leaves but to a chewing mixture made from the leaves of native species of *Nicotiana*. Cleland and Johnson (15) went into the matter very carefully in 1934 and came to the conclusion that, although the plant usually associated with the drug pituri in the various references is mentioned as *D. Hopwoodii*, the narcotic used for chewing in the greater part of Central Australia is not that species but species of *Nicotiana*, such as *N. excelsior* and *N. Gossei*. *Nicotiana* is used for chewing in eastern Western Australia and in the McDonald Range area of Central Australia. Although *D. Hopwoodii* grows in these areas, it is used not for chewing but only as a poison for trapping birds and animals. The name "pituri" was given originally to the chewing narcotic used by the natives of the southwestern Queensland area, and this was derived from *D. Hopwoodii*. Hicks and Le Messurier (23) in 1934 found definite evidence that *D. Hopwoodii* was used as pituri in the part of the Central Australian region (Musgrave Ranges) referred to by Cleland and Johnson, but only when "real" pituri, *i.e., Nicotiana*, was not available.

Following the studies on the active principle of pituri during the 1875–80 period when Petit pronounced it to be nicotine, Langley and Dickinson (35) in 1890 found the physiological action of pituri to be identical with that of nicotine. Rothera (55) in 1910 and Petrie (62) in 1917 confirmed this on chemical grounds.

Nevertheless, in view of the confusion which Cleland and Johnson had shown existed regarding the name "pituri", and because native *Nicotiana* spp. were chewed under this name, there still remained some doubt as to whether nicotine was actually present in the leaves of *D. Hopwoodii*, although some of the material which had been chemically examined did seem to have been adequately identified botanically.

Recent History and Present Position

D. Hopwoodii. In 1934 Hicks and Le Messurier (23) examined material of *D. Hopwoodii* which was collected from five locations in Central and South Australia. This material was adequately identified beyond any doubt, and they found that the chief alkaloid present in the leaves was *d*-nor-nicotine and not nicotine.

FIG. 5. Inflorescence of *Duboisia Leichhardtii*, approx. 1½ times natural size. The corolla segments are much longer than in *D. myoporoides*.

Späth, Hicks and Zajic (60) in further reports confirmed this result by establishing the chemical constitution of the alkaloid, and Hicks, Brücke and Hueber (24) studied its pharmacology the same year.

In **1943** Trautner found about 5.0% nicotine in the leaf of *Duboisia Hopwoodii*, supplied by the writer from between Boulia and Bedourie in western Queensland, 3.5% nicotine in leaf from Urandangie from a more northerly locality on the Georgina River and 2.4% nicotine in pituri prepared for smoking

by the natives of this area. These results were published by Trautner and Neufield (64) in 1946.

In 1944 Dr. Bowen (12) of the United States Bureau of Entomology and Plant Quarantine obtained a sample of leaves of *Duboisia Hopwoodii* and found that the leaves contained 3.3% alkaloid, and this was nicotine, not nor-nicotine. The origin of this sample is not known. As a result mainly of this report, interest was aroused in the possible use of *D. Hopwoodii* as a source of nor-nicotine for insecticidal purposes. Hoskins (30), therefore, in 1944 attempted to assess its economic value and the possibility of successful cultivation. He concluded that on the basis of information available it was not possible to give a final opinion but did not think that *D. Hopwoodii* appeared to be an attractive source of nor-nicotine when the lower costs of production of nicotine from tobacco waste or *Nicotiana rustica* were considered.

Then in 1945 Bottomley, Nottle and White (11), also interested in the possible utilization of *D. Hopwoodii*, examined 58 samples of leaf collected from quite a range of localities throughout the area of its occurrence in Western Australia. They found that only one specimen of the 58 contained nor-nicotine. All the others contained nicotine, the content varying from 0.4% to 5.3%.

There would now seem to be no doubt that the leaves of *D. Hopwoodii* in some cases contain nicotine to the exclusion of nor-nicotine and in others nor-nicotine to the exclusion of nicotine. On the evidence so far the alkaloid in Western Australian areas and in Western Queenslond is nicotine. The accuracy of earlier workers in their findings is thus substantiated. In South Australia and Central Australia the alkaloid is nor-nicotine. Whether or not the two alkaloids occur together in varying proportions in certain areas remains to be determined. It will be seen from the further description of the more recent work on the alkaloids of the other two species that there seems every probability that such will be found to be the case.

D. myoporoides and *D. Leichhardtii.* Investigations until 1940 sometimes found hyoscine, sometimes hyoscyamine and occasionally both alkaloids together in *D. myoporoides. D. Leichhardtii* has been studied only once.

Finnemore and the author (6) made assays of the leaf of *D. myoporoides* from 60 locations within the range of its distribution and found that the total alkaloid content varied from 0.6% to 3.1% on a dry leaf weight basis. A determination of the major alkaloid was made in 22 samples with the generalization that in material from northern New South Wales and Queensland hyoscine predominated, whilst in material from the more southern areas just north and south of Sydney hyoscyamine was the major alkaloid. A method for extraction of hyoscine from the northern material was rapidly developed, and in 1941 commercial production of hyoscine was commenced by Felton, Grimwade and Duerdins Pty Ltd., a local manufacturing firm. The yields were far superior to those obtained from previously known sources. During the war emergency some 7000 ounces of hyoscine were produced in Australia from this new source. This amount is said to be greater than the amount previously produced in the world.

Because of extraction difficulties, comparable success was not experienced in producing atropine from southern *D. myoporoides.* The hyoscyamine could not easily be separated and crystallized. During the latter part of 1941 and the early part of 1942 Finnemore and the author (6) examined leaf samples of *D. Leichhardtii* and found a total alkaloid content of from 2.7% to 3.0% in which hyoscyamine largely preponderated, al-

though hyoscine was also present. The hyoscyamine extracted well and could readily be isolated in a pure and crystalline form. Commercial production of atropine from this source then commenced. Lean and Ralph (37) and Willis and Ralph (71) further experimented with the production of hyoscyamine from *Duboisia* and published their results in 1944. They found that all their samples of *D. Leichhardtii* contained hyoscyamine or a mixture of hyoscyamine and hyoscine with the former preponderating. Whilst fewer difficulties were experienced in the extraction of hyoscyamine from *D. Leichhardtii* than from southern *D. myoporoides*, they found that samples from some locations in the south extracted more easily than others and actually quite well. They observed also that a clear crystalline product was also more readily obtained in material collected during autumn and winter than during late spring and summer when syrupy bases were most pronounced in the extract.

During the same period (1945) Hills, Trautner and Rodwell (25) examined 82 leaf samples of *D. myoporoides* and *D. Leichhardtii* from single trees. Although considerable individual tree variation occurred, the generalization stated by Finnemore and the author in 1941 was confirmed. It was found that the nature of the alkaloids and the balance of hyoscine and hyoscyamine could change throughout the season. Selection and testing of different types of the two species and cultivation trials were undertaken by Hills and Rodwell (26) and Hills and Kelenyi (27). Hills says: " Although the genetic-environmental relationships of the alkaloid complex are somewhat involved, it has been possible to isolate types which yield hyoscyamine under any environmental conditions and others which yield hyoscine in most circumstances. In many cases the alkaloids are present together, the proportion of each depending on the environmental conditions and the genetic nature of the material ".

Since 1945 Trautner and Shaw (65), Trautner, Neufield and Rodwell (66) and Trautner and Roberts (67) have described improved methods of assay of alkaloids in *Duboisia* spp.; Trautner (68) has discussed alkaloid formation, and Mitchell and Trautner (43) have contributed to the study of the minor alkaloids of *D. myoporoides*. Mr. Hills has done experiments on the vegetative propagation of the species, in which he found that softwood tip cuttings were satisfactory. Hills, Trautner and Rodwell (28) made grafting experiments in which tobacco and tomato scions were grafted to a rootstock of *D. myoporoides*. They concluded that the alkaloids or their precursors were formed in the root of *Duboisia*, and finally the author (28) has described the life history of the two species *D. myoporoides* and *D. Leichhardtii*.

At the present time *D. Leichhardtii* is being increasingly used as a source of atropine and hyoscine, mainly because bulk collections of this species yield the two alkaloids in the appropriate ratio economically required.

The rapid growth and very high alkaloid yield of *Duboisia* should ensure its becoming the principal world source of hyoscine and also possibly of atropine in the future.

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Utilization Abstracts

Conifer Foliage Oils. In 1946 Canada exported 36,300 pounds of cedar leaf oil, valued at $2 a pound, and 23,600 pounds of pine needle oil to the United States. In the same year the U.S. imported additionally 69,800 pounds of Siberian pine needle oil from the U.S.S.R. Because of the market implied by the later figure for greater production of the Canadian oils, the Ontario Research Foundation in Toronto has undertaken investigations into the greater production and utilization of these oils from the foliage of black spruce, eastern white cedar, hemlock and Canada balsam.

Black spruce produces about one pound of foliage for every four or five pounds of wood, and with more than a million cords of black spruce cut annually in Ontario, an estimated 540 million pounds of spruce foliage are thus available, capable of yielding about five million pounds of volatile oil. Perfume and flavor industries, which at present are the principal consumers of these oils, could not under present conditions consume that much. New uses must, therefore, be found either for the oils as a whole or for certain of their constituents. Black spruce leaf oil, for instance, is one of the richest natural sources of bornyl acetate (37%), a basic ingredient in almost all perfume compositions possessing a pine odor. It may be used also for synthesis of camphor. (A. C. Shaw, *Canad. Chem. & Proc. Ind. 35: 44. 1951*).

Carnauba Substitutes. Carnauba wax, imported from Brazil where it is obtained from the leaves of the palm *Copernicia cerifera*, is the most important industrial wax used in the United States. "The valuable properties of carnauba wax are gloss, hardness and the fact that it can be dissolved in solvents for paste floor wax or paste shoe polish. In addition, carnauba can be saponified for water emulsions for a great variety of household and industrial uses. Self-polishing, water-emulsion floor waxes, the so-called 'no-rubbing waxes', take the major share of carnauba wax. The wax film which remains on the floor after the water has been evaporated is subject to heavy wear. Emulsion waxes made with carnauba produce a glossy, hard and lasting film".

Advancing prices of this valuable wax have compelled users of it to look for suitable substitutes, and five classes of possible substitutes are available, namely, animal waxes, vegetable waxes, synthetic waxes, petroleum waxes and composition waxes. "The first requirement of a substitute for carnauba wax in floor wax emulsions, besides gloss and hardness, is a high melting point. Federal specification calls for a softening point for the solids of not less than 80° C. A second requirement is that the emulsified wax not be a cloudy liquid but a transparent one, especially when laid down in thin layers".

Among the possible vegetable substitutes, refined ouricury from the Brazilian palm *Syagrus* (*Cocos*) *coronata* comes closest to carnauba in both price and properties. Refined candelilla wax from the stems of two desert shrubs of Mexico and the American Southwest (*Pedilanthus Pavonis* and *Euphorbia antisyphilitica*) is another suitable substitute, and refined sugar-cane wax a third. This third wax, "first produced in Natal, Africa, was used during World War I in England as substitute for carnauba wax in shoe polishes. As a byproduct of cane sugar it is available today from sources in Australia, Cuba, California and Louisiana, the imported wax being less expensive than the domestic wax". (A. A. Kroner, *Soap & San. Chem. 27(3): 110. 1951*).

Some Observations on the Cultivation of Kenaf

In the breeding work performed so far on this substitute for strategically important jute, several desirable features have been overlooked, the genetic factors for which may be hidden in the various wild strains of Africa.

A. E. HAARER [1]

Introduction

The Western Powers have rightly been anxious about the supplies of strategically important soft fibres because the world is greatly dependent on India and Pakistan for jute, the most important of those fibres. The relations of these countries with each other have not been very satisfactory, their supplies of fibre and price factors have been disturbed, and both countries happen to be in a region which cannot now be considered safe in the event of another World War.

Those in control in Britain who are detached from vested interests concerning the jute industries of these two Dominions are just as anxious regarding the future security of supplies as are well informed Americans. The soft fibre trade is, however, so deeply and so financially involved in jute that it might stupidly oppose any British move that might undermine the strength of the Dominion interests in jute, at least until an enemy had cut off supplies! Not so America, to the great relief of many, such as the writer. It is therefore with a desire to be helpful that the following observations are made.

Objectives of Research

Investigations into the possibility of cultivating kenaf as a jute substitute on a large scale have overlooked many apparently minor but actually important points. The chief anxieties of recent years have been *a)* concerned with selecting and hybridizing various strains to give the highest yields wherever they are grown; *b)* to discover nematode-resistant strains; *c)* to hasten and cheapen the process of retting; *d)* to mechanise every stage of production because of the scarcity and high cost of labour in the Western Hemisphere; and *e)*, most of all, to develop mechanical extraction of the fibre to avoid the tiresome process of retting.

To start with, there is the question of high yields. Plant breeders have been endeavouring to select the tallest unbranched and the highest yielding plants without giving much consideration to the difficulties of harvesting and to the fact that long hanks of fibre are difficult to handle and bale, and may not be desired by the spinners. This urge to get the biggest possible yield instead of a sound and sure economic average has been a common fault with most of the recent big development schemes. Correlated with attainment of higher yields should be a close investigation into ways and means of maintaining soil fertility and structure when they are put to such a strain.

When complete mechanisation is arrived at, it is necessary to breed a crop of a stature and kind that will lend itself to mechanisation rather than place too great a strain on the inventive genius of the engineer. When the yield is high the fibre tends to coarsen, and the one bad fault with kenaf, as with most other *Hibiscus* fibres, is that the fibre is a little too coarse and not flexible enough in

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comparison with jute. Most spinners agree that this lack of flexibility is the most important fault which needs to be overcome by selection and plant breeding.

With most of the other fibres very little has been done to breed strains producing fibre for special purposes. Work is only now being done in New Zealand with *Phormium tenax* to select for fineness of fibre, on the one hand, and coarseness, on the other, and selection of strains of sisal for fibre quality has only recently been started in East Africa. Fibres have been accepted by industries because they have fitted the purposes for which they have been used, whereas kenaf must be made to give satisfaction as a complete substitute for jute by the discovery of strains which produce a more flexible fibre.

It appears that another important consideration is concerned with seed production. Authorities agree that it is unsound to endeavour to collect seed from part of a field grown for fibre (3). Growth is too tall and spacing too close in such a field, so that harvesting is difficult and the yield of seed is poor. Instead, it appears advisable to sow separately and at a later date for seed, so that the crop does not grow so tall on account of photoperiodicity, and may be planted at a wider spacing.

Two suggestions may be put forward. One is that seed production be entirely divorced from fibre production, and the seed taken to a latitude near the equator where the hours of daylight are always short. The result would surely be a stunted plant, maturing in a much shorter time, which could be spaced closely and handled and harvested with greater ease. Sites might be chosen where several crops may be attainable in any one year because of more than one growing season or by use of irrigation in a land, such as Africa, where labour is comparatively cheap.

The second suggestion may be considered retrograde. It is that the aim to produce a tall unbranched stalk be somewhat diverted towards a strain that will forego branching when spaced closely but will produce more branches and hence a higher yield of seed when it is given more room. The aim at present is at an extreme rather than at a happy medium.

Kenaf has been grown extensively in India beyond history, and considerable quantities are now exported from Madras under the name of " Bimlipatam jute ". Elsewhere it is called " Deccan " or " Ambari hemp ", and by many other names, and one wonders why Americans call the plant " kenaf ", after the Russians who took it from the Persians when they first collected material near the shores of the Caspian Sea (1). The Howards (4) were the first to carry out any selection work. In later notes, the Howards spoke of their Type 3 which was afterwards propagated and distributed in India (5).

In spite of this work, the seed introduced into the southern States of America, Cuba and elsewhere in the Western Hemisphere appears to have originated in a somewhat haphazard way from the Dutch East Indies, and efforts have been made to match the resulting forms with Howard's types. The *viridis* variety of Cuba cannot possibly be the same as Howard's original *viridis* which he described as an inferior type, since it had short branched stems.

There is little mention, if any, in Western literature of an attempt to introduce Type 3 which was the one most favoured in India. In fact, when *Hibiscus cannabinus* seed was first grown and tested in the southern States, it was mistakenly referred to as " roselle " (3).

It seems, therefore, that when once the all important question of mechanised production and economic yield has been satisfactorily dealt with, a great deal more attention should be given to the

origin of the present strains and to the possibility of collecting as good, if not better, material elsewhere. The Bimlipatam jute exported from Madras to the United Kingdom is said to be inferior to jute, but this is because it is retted and prepared by a multitude of peasant cultivators, and because, when it is properly prepared, it is a little less flexible.

This fault is not of much import in the manufacture of gunny bags and burlap, provided spinning machinery is adapted to its use, since from all accounts the fibre can be used for this purpose and is said to be much stronger. Emphasis at present is on persuading the spinner to adapt and put up with the fibre he is offered.

Photoperiodism

The photoperiodicity of kenaf raises many important problems. With regard to the types cultivated in Cuba and elsewhere, they all begin flowering within a short period of time, regardless of when the seed is sown after the rains begin. Between early and late sowings, and early and late selections from the local types, a difference of only a few days in the date of first flowering has been obtained, since the types grown are short-day plants which all initiate flower buds when the days are shortening to 12 hours of daylight.

The critical time for harvest is agreed by many to be after the first flower has opened but before the lowest capsule is mature (3). It is at this time that the yield of fibre is satisfactorily high and its quality the best. Mechanical decortication is easier at an earlier age when the stems are softer and filled with more sap, but the yield and quality then suffer. Decortication must not be delayed beyond the critical first flowering; otherwise the stems begin to become too tough and fibre extraction is increasingly more difficult.

This critical period of a few days duration creates difficulties when harvesting. How is a large acreage of many thousands of tons of green material to be decorticated in such a short while? One must allow for many small mobile combined harvesters that extract the fibre and leave the waste material as a mulch on the ground, or install large top-heavy central decorticating plants that can run only for a short season and then close down. Mobile decorticators must, therefore, be the best method, especially if it were possible to move from latitude to latitude and contract to harvest successive crops which mature according to a difference in the hours of daylight.

South Africa has overcome the difficulty of harvesting during a short critical time by cutting and drying the stalk in the field. The straw is then stacked at retting centres to await its turn without deterioration. After the straw is retted it is scutched in a way similar to the treatment of flax on adapted jute softener machines. The authorities do not as yet claim that this method is perfect, and, on account of faults during harvesting and drying, the fibre is not always of good quality. The main difficulties have been overcome, however, and it now remains to improve the methods and the machinery.

To simplify the task of harvesting and decorticating large areas of kenaf, it is necessary somehow to stagger the time when the crop matures. The response of different plants to the hours of daylight, known as "photoperiodism", is not to be confused with early or delayed maturity. A whole race of plants may show photoperiodicity for either a short or a long day, but this does not preclude selection from them of some that mature early and others that mature later. Beyond this there are many races of plants that would appear to grow and flower and arrange their span of life irrespective of the hours of daylight.

In Cuba the daylight shortens in September after several months of longer days beginning in early April. For fibre production the crop is there sown in April and May as soon as the rains begin, so that the plant has at least four months to develop a tall stem and therefore a good yield of long fibre by the time flowering begins. For seed production, however, the crop is sown in July, so that growth will be much shorter to enable the ripened seed capsules to be harvested by mechanical means with greater ease and less loss.

Hibiscus cannabinus as a whole has not been closely studied, and other research workers have pointed out that some varieties are variable concerning their photoperiodic response (7). This has recently been shown in Cuba during the breeding programme when selections from Cuba and El Salvador were being tested against seed from Korea and Manchuria (2). The Asiatic material matured much earlier and gave smaller yields of fibre at the Cuban latitude. This would seem to prove that they were extra sensitive to shorter hours of daylight than were those in Cuba.

Bearing all this in mind, one must next consider the fact that *Hibiscus cannabinus* grows wild and is indigenous throughout Africa at all latitudes where fertile soils, warmth and sufficient moisture allow the plant to grow successfully. The extraordinary feature is that it grows as tall before it flowers near the equator in East Africa where the hours of daylight are no more than twelve, as it does in Egypt or the Transvaal!

We must therefore conclude that the wild plant of Africa varies in its photoperiodic response from latitude to latitude, having probably adapted itself and become fixed in this character in ancient times. From the plant breeder's point of view this should be investigated, for it would be not only of great interest but perhaps of great economic importance. Differences which might be of great importance to the fibre industry would be discovered only by collecting seed from what we may call " latitudinal clines " and by sowing these side by side for comparison wherever an industry is begun.

Russian breeders of kenaf are envious concerning the material we have. They say they must make the best of their own material originating from Persia and the East until such time as they can obtain seed of the African types (6). Meanwhile in the Union of South Africa the tendency is to abandon the local types, no doubt wisely for the moment, in favour of imported seed from Brazil and Egypt.

A great deal might be done to separate early and late maturing strains from each latitudinal cline, and to make use of the variation in photoperiodic response to widen the critical time during which harvesting must begin and end. Early and late maturing types have been reported from India and Persia, and we have not yet awakened to the potentialities of the wild types in Africa. We shall not learn much until our research workers get busy along these lines. Since a wealth of possibilities and facilities lie outside our doors, it does seem a pity that a greater interest in these wonderful fibre plants has not yet been taken to a sufficiently exhaustive degree.

There are those who argue whether *Hibiscus cannabinus* originated in Africa or Asia. If it is proved that the plant does indeed grow in clines on the continent of Africa, and that the races elsewhere in the world vary only to a slight degree in their photoperiodic response, then it would seem to prove that the races in Africa are more ancient and that seed must have been taken to other places in the world from only certain parts of Africa during the dim and distant past.

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Utilization Abstracts

African Oil Palms in Honduras. In the search for new crops for Latin America and for means of combating the world shortage of edible oils, the United Fruit Company in 1942 began an investigation of the possibility of producing palm oil in Honduras. Selected varieties of African oil palm (*Elaeis guineensis*) from the East Indies, Malay States and West Africa were planted in subsequent years, and the Java variety was found to be the highest yielding. " Results of this work indicate that the Java and Sumatra varieties can be placed in the superior ' Deli ' type, known in the East as *Elaeis guineensis* form ' dura ', Baccari. All palms of this type were propagated by the Dutch from a few superior selected plants and the preponderance of the same or closely related types in the large plantings in the East Indies indicate their inherent stability. The Sumatra variety can be classified as average ' Deli ' type palm while the Java type seems to be a superior strain of ' Deli ' ".

An oil-splitting enzyme in the pericarp of the palm fruit becomes active when the exocarp is broken and causes decomposition of the palm oil into free fatty acids and glycerol. For human consumption an edible oil containing up to 5% free fatty acid can easily be refined, and for the tin-plating industry, one of the industrial outlets for vegetable oils, the oil should not have more than 7.5% free fatty acid. The oil-splitting enzyme can be destroyed by heat, and " it is customary in the factory processing of the palm fruit to sterilize the bunches at a steam pressure of 30 p.s.i. for from 45–60 minutes. This heat treatment of the fruit not only destroys the enzyme but also facilitates the subsequent stripping of the fruit from the stalk ". It was not known, however, how much time can elapse between harvesting and the heat treatment so that the percentage of free fatty acid would not increase to an undesirable extent. This was investigated, and " less than 1.5% of free fatty acid was found in the oil of sound fruit which was sterilized from six to 23 hours after harvesting. Oil from bruised fruit had a higher percentage of free fatty acid, with one sample exceptionally high (14.74% at 23 hours) ".

" This investigation proves that commercially harvested mature fruit can be sterilized up to 24 hours after harvest without deterioration of the quality of the oil; that bruising of fruit should be avoided as much as possible; and only completely mature fruit should be harvested if sterilization is to be delayed ". (E. O. Reif, *Jour. Am. Oil Chem. Soc. 28: 152. 1951*).

Stillingia Oil. *Stillingia sylvatica*, commonly known as Queen's delight and Queen's root, is a shrub of the Euphorbiaceae, native from Florida to Texas and from Missouri to Virginia. A root extract of it has had medicinal use for many years, and recent investigation has shown that the seed oil may be suitable as a drying oil for paints and varnishes. (V. C. Batterson & W. W. Potts, *Jour. Am. Oil Chem. Soc. 28: 87. 1951*).

Supplementary and Emergency Food Plants of West Africa

The occurrence of famines in various parts of the world, especially in primitive tropical areas, has compelled the inhabitants of those regions to subsist at such times primarily on an enormous variety of wild plants, a few of which are discussed in this article, that otherwise would be relatively little utilized by them.

F. R. IRVINE [1]

Introduction

Experts tell us that we need to double our present output of food in order to feed the population of the world 50 years hence, a steady increase in the number of mouths to be fed necessitating a steady increase in the food supply. In some parts of the world masses of the people are more than half starved, while the proportion of such persons in, say, America or Britain, is much less. There were famines in Russia after the first World War, in Greece and other lands after the recent war, and China has long been well known for them, millions of Chinese having suffered alike from the pressure of population and from the vagaries of the Yellow River with its floods and devastation. Famine conditions, however, are more to be expected in certain tropical and sub-tropical lands than in temperate countries, and several Royal Commissions have tried to deal with them in India where masses of the inhabitants might be said to be normally undernourished. It is with conditions in Africa, however, that we are primarily concerned in this article, and all references here to the natural occurrence, cultivation and utilization of plants, unless otherwise specified, will refer to West Tropical Africa.

Africa is a " hungry " continent, and the main cause is probably climate, namely, drought, but wars and insect pests have also been important factors in the starvation conditions that have prevailed there on many occasions.

There is no doubt that droughts have been foremost in bringing about these conditions, especially in the northern, eastern and much of the southern parts of the continent, and it has been claimed that Africa is becoming more desert-like as time goes on, as is evidenced by arid conditions today where the remains of Roman cultivation in North Africa are still evident. The " emergency foods " of Africa are best studied in at least two regions—the great Sahara Desert of northern Africa and the Kalahari Desert in the South—and some of the famine food plants described in this article are characteristic of those regions. Further light on the problems of human nutrition in desert regions may be obtained by studying the food plants of the aborigines in central Australia.

In past ages, before the coming of Europeans, wars swept across Africa. Negro empires rose and fell. These periods have been chronicled by Arab historians, and the empires referred to were largely in the drier parts of West Africa, around Timbuktu, the Upper Niger and other centres. In later times the European-run slave trade not only

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caused countless wars in Africa but depended for its slaves on already existing wars, the prisoners being eventually sold in the European slave forts at the coast. Famine and desolation followed these wars and raids, as any one who has read the writings of Livingstone and other travellers must realise. But even since abolition of the slave trade there have been wars on the Gold Coast, such as the Ashanti wars during the past 150 years, with their resultant famines.

The chief insect pest in Africa is the locust. There are several species, the migratory, the red and the desert locusts being the main ones. They come in mass clouds to attack the food plants, not only of man but also of his domestic animals, and more damage is done by the hoppers, or immature wingless forms, than by the adult locusts. The migratory species appears to attack monocotyledonous plants only, *i.e.*, all members of the grass family, both cereals and pasture plants, as well as coconut and oil palms, plantains and bananas. The last four, being perennial, unlike the cereals, can recover.

Finger millet, or bulo (*Eleusine corocana*), which in Uganda in 1935 was the second most important food crop, covering 872,000 acres, is attacked by locusts, devoured when young by water buck and parasitised by *Striga*. Famines in olden times were particularly severe in the grain areas of Uganda, and the same is true of the Nankani area in the Northern Territories of the Gold Coast. A more diversified system of cropping, especially including such " root " crops as sweet potatoes, cassava and ground nuts, have gone far to reduce both the frequency and intensity of famines. During the 1928–29 famine in Uganda, large areas of sweet potatoes, planted in time, greatly alleviated conditions. They are a dependable reserve food crop at such times, and during the locust infestations of 1930–32, when grain crops were destroyed on a large scale, thousands of Africans would have perished but for their aid. Cassava (*Manihot esculenta*), too, is valuable as an emergency crop in raids of the migratory locust, for it is not attacked by that pest, and large areas of the crop were planted in Uganda to meet the locust outbreak of 1930–33.

It is not with such strictly cultivated crops, however, that we are primarily concerned in this article, but with those that grow wild or are only incidentally tended by Africans. From the viewpoint of the student on the spot it is difficult to define exactly what constitutes a famine food. African agriculture is in all stages of development, and its edible plants may be classified as follows:

a) Those eaten only in times of real emergency or famine.

b) Wild foods ordinarily gathered but not sold in markets.

c) Wild foods gathered and sold in markets.

d) Semi-cultivated plants, tended as they grow up in the " bush ".

e) Cultivated crops, planted and tended by man on farms.

Those under *a* definitely and those under *b* and *c* to some extent come under the heading of this article, for a famine food not only is one restricted to times of scarcity, *i.e.*, *a*, but may also be a wild food collected more or less regularly without being sold, *b*, or even one gathered from the " bush " and sold, *c*. The point at issue lies rather in the nutritive value of such wild plants as compared with those of more established character, the partly or wholly cultivated, *d* and *e*. The food value of the latter is well known, whereas that of the strictly wild or emergency plants needs further investigation, a study which would undoubtedly throw interesting light on the origin of man's food habits and of his agriculture.

The origin of human food provides

interesting study, and one can visualise early man, in his search for food in times of scarcity, learning to select and consume the wild plants that grew about him. He was a close observer of nature and knew the food habits of other animals. In the early days at the Cape of Good Hope, primitive man followed the hedgehog and bavian (baboon), and would not taste any root or fruit which those creatures did not eat. A few years ago Dr. George Taylor, a botanical explorer, observed Tibetan bears eating leaves of wild rhubarb (*Rumex*) and then ate some himself without harm. With the exception of a few poisonous bushes, most trees provide food for the Turkana in East Africa. It is possible that vegetables, as we understand the term, *i.e.*, plants specially cultivated to serve as vegetables, were among the last discovered foods of man. The Latookas (Lotuko) of Central Africa in the middle of the nineteenth century did not know of any vegetables and did not even grow pumpkins; and in other parts of Africa it was reported at that time that no vegetables were eaten except gourds, common purslane and the fruit of *Borassus*.

Famine foods of both mineral and animal origin, as well as those from vegetable sources, are known. Wild animals used as famine fods in tropical Africa are of great diversity and include many unusual vertebrates as well as invertebrates, with many kinds of insects. This suggests that protein shortage is the main cause of their use. The animal foods of African peoples, from wild sources, is worthy of further study.

Famine foods of vegetable origin include a variety of plant organs, the most frequently used among which are: *a*) starchy enlarged rhizomes, roots and aerial tubers; *b*) leaves of perennial plants, either woody or having perennial rootstocks; *c*) pulp of fruits of perennial, especially woody, plants; *d*) seeds of certain wild grasses. Other parts of plants are also eaten, and it is under these categories that some of the many species of plants which contribute to this class of human sustenance are noted in this article. The information presented has been gathered from a variety of sources in the literature on the subject, the principal one of which is "The Useful Plants of West Tropical Africa", written by Dr. J. M. Dalziel, late of the West African Medical Service, and published by The Crown Agents for the Colonies.

Rhizomes, Roots and Aerial Tubers

The enlarged underground portions as well as the aerial axillary tubers of many kinds of plants have been among the main sources of wild food, both of early man and of primitive man today, as well as of emergency foods in times of famine.

Yams. The term "yam" as used in the United States refers to certain varieties of sweet potato (*Ipomoea Batatas*), but in a more world-wide sense it refers to the swollen underground edible portions of tropical vines in the genus *Dioscorea*. It is in the latter sense that the term is employed in this article.

Several species of *Dioscorea, e.g., D. macroura* (= *D. sansibarensis*), *D. Preussii* and *D. smilacifolia*, cultivated or semi-cultivated in tropical Africa, furnish yams which have been used as famine foods, and others which are poisonous. The Warenga people in Central Africa not only cultivate them but use wild species as well, and in West Africa there are several which are definite famine foods. Probably the best known of these is the bitter yam (*D. dumetorum*), known as the "cluster yam" when its tubers are clustered. Not only has it served as a famine food on the Gold Coast, but in 1938, when starvation conditions prevailed in the Blue Nile Province of the Anglo-Egyptian Sudan, it was the principal one among a dozen or so different roots and tubers that helped to alleviate the situation.

Strictly wild forms of this yam are poisonous and have allegedly caused deaths in the eastern Sudan. The symptoms of patients suffering from such poisoning in 1938 have been described, but the symptoms recorded may be caused also by dry beri-beri. Corkill, however, was of the opinion that certain deaths during that famine definitely resulted from consumption of improperly detoxicated yams and that the local people were becoming fearful of their staple famine food. Death would occur within one day after eating unprepared yam, even after only three hours in the case of a child. The interval between eating of the yams and death varied from three hours to seven days. In West Africa certain types of *D. dumetorum* are sometimes planted around the edges of non-poisonous yam plantations in order to discourage monkeys and would-be thieves.

The toxic principle in this yam is dioscorine which paralyses the nervous system. The closely related Asiatic *D. hispida*, which also contains this toxin, is used by the Bhils, a primitive hill tribe of India, as a tiger poison, and in Malaya it is a dart-poison adjunct, in Sikkim an arrow poison, and in Java a fish poison. It is said to be poisonous also to fowl. *D. dumetorum* has been used in Africa as an ingredient in *Strophanthus* arrow poisons, and is employed by the Zulus to catch monkeys, which it stupifies.

Dioscorine, since it is soluble in water, can be removed from the yams by first killing the tissues that contain it and then by washing it out. Safe use of the tubers by the Africans has therefore involved boiling, peeling, slicing, pounding and then steeping them in running and preferably salt water, a detoxication process which generally requires about three days. Sometimes hot water is used for the steeping, and at other times the tubers are buried in black cotton soil, known as " bardob ", for three days before being ground into flour and made into Kisra. The steeping is occasionally done in a mixture of water and cotton soil, also for three days; and sometimes tamarind pods (*Tamarindus indica*) or desert dates (*Balanites aegyptiaca*) are used as detoxicators. After such preparation the tubers are either eaten whole or ground into flour and consumed as porridge, with or without sesame seed, or as unleavened bread. In certain East Sudan villages, *e.g.*, Shilluk, they serve as a basis for beer, apparently without any detoxication process being required.

In preparing and testing *D. hispida* in the East Indies, a common famine food in other parts of Asia also, it is reported that the presence of shrimp or fish around a basket of yam steeping in running water is a good sign, whereas the curling up (" writhing ") of dry slices of yam is regarded with suspicion. Preparation is considered incomplete if fowl, fed on the yam, turn giddy, and also if a drop of fluid from the prepared mass, put into the eye, causes smarting.

In the course of tending these tubers over the centuries, the African natives have selected less bitter varieties, and in this way cultivated forms have been acquired, though not exclusively relied upon, which are almost free of the poison and whiter or paler yellow. Similarly in the Malayan *D. hispida* dioscorine has been almost eliminated by cultivation, and improved races with whiter tubers have been produced. During famines the main value of *D. dumetorum* has been in the calories that it provided, though it also contributed protein to the diet and, like the potato in the Irish famine, seems to have been the principal anti-scorbutic food because of its content of ascorbic acid, especially when prepared with tamarind.

Among other species of *Dioscorea* there are *D. hirtiflora* which is not cultivated or eaten in French Guinea but is grown in parts of Sierra Leone and in

northern Nigeria; *D. Preussii* with a caustic tuber which is eaten in times of famine but only after prolonged soaking; and *D. minutiflora* (*D. praehensilis*) on the Gold Coast where it is probably eaten under similar circumstances and is known in the Twi tongue as " aha bayere ".

Finally there are those species and varieties of *Dioscorea* which produce edible, aerial, axillary tubers. Probably best known of them is the bulbil yam or air potato (*D. bulbifera*), the aerial tubers of which sometimes weigh several pounds, while those of subterranean formation are too small or too acrid to be used as food. Variety *anthropophagorum,* which differs from the type only by its aerial tubers being angular, is both wild and in cultivation, and its tubers are used medicinally in the preparation of poultices. Such usage, as in the treatment of ulcers, probably depends upon their content of pain-killing saponin. This variety provided food during the Madagascar rebellion of 1948, at which time they were scraped and cooked in water with wood ash, then placed in running water for four to seven days, and subsequently eaten directly or first reboiled. Despite this treatment they retained their natural bitter flavor and caused heaviness, though they did satisfy hunger. This variety is known in both edible and poisonous forms, and the latter are sometimes deliberately planted among the former to deter thieves who do not know the relative positions of the two.

Other Roots and Rhizomes. In Europe a common field crop, the mangel wurtzel, a form of beet with often huge roots regularly fed to farm stock, may have been utilized in former times as an emergency human food. In Africa the Gulla are reported to live on wild roots in times of crop failure, and the Hottentot women dig up edible roots that abound in their country, washing them before cooking.

The rhizomes of water lilies (*Nymphaea Lotus* and probably other species) are either eaten raw or first cooked, and form a useful human food in many parts of the world, including West Africa. In Upper Guinea they are used mainly in famine times, when they are either roasted in ashes or dried before being ground into flour. Their use as famine food among the Thonga of South Africa has been described, as well as among the Lango (A. E. Sudan), and in the Sudan the Dinka use them in making a kind of meal like sago.

Dr. Kirk, who travelled with Livingstone, noted that Africans of the Zambesi region ate the soft and starchy roots of a capparid, *Boscia salicifolia.* Among the wild African Leguminosae that produce edible tubers are *Eriosema cordifolium* and *Psophocarpus palustris,* the latter being apparently indigenous to West Africa, though not cultivated and used there, as it is elsewhere, for its edible rhizome and for its young winged pods. Several species of *Vigna* are reported as furnishing edible tuberous roots, one of which, *V. vexillata,* has enlarged and sometimes divided spindle-shaped root-stocks. One form of it is said to be eaten in Abyssinia and South Rhodesia.

The asclepiads form one of the main families in Africa to produce edible roots. Those of *Asclepias lineolata* contain inulin and are consumed on the Ivory Coast, either raw or pounded and boiled, while those of *Raphionacme Brownii* are reputedly so refreshing and nutritious that a man can subsist on them alone for an entire day. The latex of the latter is free of any rubber-like components and has been reported to be an excellent thirst quencher; in fact, the Fulani of northeastern Nigeria refer to the root of *Raphionacme* as the " water bottle ". Both they and the Mandingo eat the " roots " raw or cooked but avoid excess use of them lest they cause colic. The tubers of another asclepiad, proba-

bly *Cryptolepis nigritana*, are also eaten in times of famine, and the well-known genus *Ceropegia*, consumed by the Malinké of French Guinea, furnishes several species with edible tubers. Others of the genus from the Upper Nile and Abyssinia are said to taste like Jerusalem artichokes when cooked. Several species of *Brachystelma* with edible tubers occur in South Africa and Abyssinia, while in West Africa *B. Bingeri* is reported as being eaten raw after the milky resinous outer layer of the tuber has been removed. It consists mainly of starchy matter, and Europeans use it, boiled, as a substitute for turnips, despite a slight bitterness resulting from the resinous content. Other asclepiads with edible tubers occur in Madagascar.

The young and tender roots of the baobab tree (*Adansonia digitata*) are edible, and the tubers of *Tacca involucrata*, about the size of one's fist, are collected from wild plants by several West African tribes. In some parts of West Africa starch is obtained from them, but they are acrid, caustic, inedible and almost poisonous, and may be eaten in times of famine only after preliminary boiling. A coarse meal, known as " amara ", is prepared from the wild tubers by the Munshis of Nigeria, while among the poorer Adamawa Fulani some of the ground flour, along with prepared cereal flour, is brought by a bride to her new home as an indication of her ability as a housewife. The Munshis, when they discover the plant growing on land cleared for yams, allow it to remain, and it may thus be regarded as being partially cultivated. Dalziel says that it is edible only after being improved by cultivation, but he does not mention any exact district where such cultivation is pursued, unless he refers to this semi-cultivation of the Munshis. An Oriental species, *T. pinnatifida*, native to tropical Asia and Polynesia, is reported as being cultivated in Siam, probably also in the northern parts of the Malay Peninsula, and locally in parts of the Pacific, East Asia and East Africa. Here again the fresh tubers are bitter, but after being rasped and soaked they yield a starch, a pure form of which, known as " Tahiti arrowroot ", is a good food for invalids.

This is true also of the starchy rhizomes of the Indian shot or balisier (*Canna bidentata*) which are consumed in West Africa in times of scarcity after proper preparation. Similar use has been made of *Canna indica* in India. A closely related species is Queensland arrowroot (*C. edulis*), known in the West Indies as " tous les mois ", the purplish rhizomes of which are cooked and eaten by the Tamils who also make flour from them. The plant is cultivated and propagated the same way as ordinary or West Indian arrowroot (*Maranta arundinacea*) is in Queensland for its very soluble, easily digested, starchy " arrowroot ".

One of the gourd family, *Trochomeria Dalzielii*, has yam-like roots, often produced deep in the ground, which are dug up at the end of the rains, boiled and eaten, and sometimes even used medicinally in West Africa.

Various wild species of the sword lily, or corn flag (*Gladiolus*), occur in Africa, and some of them are cultivated. All produce starchy corms, the larger being obtained from *G. Quartinianus*, the smaller corms and flowers from *G. unguiculatus* and *G. Klattianus*. The smaller corms are eaten in soup and sometimes sold in markets for that purpose; the larger are used along with Guinea corn flour to make a sweet pap or beverage. In southern Africa, too, where other species of this genus are found, several of them are used for food.

The labiate, *Solenostemon ocymoides*, is sometimes cultivated and is well worth growing, being very similar to the West African root crop, *Coleus dysentericus*, which is indigenous there. In addition

to the edible leaves of the former, small tubers which can be eaten may be formed by its roots.

The "roots" of *Ipomoea aquatica* (Convolvulaceae) as well as its young shoots and leaves are universally used as food, and the plant occasionally comes under semi-cultivation for this purpose.

The tuberous root-stock of *Dissotis grandiflora* (Melastomaceae) contains sugar. The roots are washed, half dried in the sun, beaten in a mortar and steamed. When cool they are squeezed by hand, and the juice obtained is used for sweetening purposes. A fermented beverage is also made from this sugar. The tubers have been found to contain 66.6% water, 4.8% cane sugar, 20.8% reducing sugar.

The large tubers, up to 18 inches long and over one foot in diameter, of the wild *Icacina senegalensis* also yield starch. They are eaten alone or, more often, together with a starchy meal made from the seeds, by the peoples of the Upper Shari region in times of cereal shortage. The tuber is cut up and placed in running water to remove its bitterness and to facilitate maceration. It is then dried, pounded and strained to remove the fibres. A paste prepared from it with boiling water and consisting mainly of starch is said to be of good appearance and agreeable taste. In 1896 or 1900, when the small British garrison was surrounded at Kumasi, the capital of Ashanti, it is said that wild tubers of this species were eaten and that those who ate them died a few days later, showing various symptoms, such as swelling of the face. Other symptoms from the same cause have also been reported. In the same wars the tuberous roots of *Smilax Kraussiana* are also said to have been used as food.

Wild orchid roots have been reported as being gathered in September in North Rhodesia by Bemba children but as being regarded elsewhere with contempt. A passing Lunda, for instance, is said to have remarked: "In our country we just divorce our wives if they serve orchid relish, whereas yours (*i.e.*, Bemba) have to cook it every day". Salep, an article of commerce prepared from species of *Orchis* and *Eulophia*, another orchid genus, is more a medicinal substance than a food. Since salep forms a jelly when soaked in water, it is popularly regarded as highly nutritious and is sold to be used the same way as arrowroot. Its food value, however, is more apparent than real, for, though rich in mucilage and containing some sugar and albumin, it has comparatively little starch.

The rhizomes of several aroids (Araceae) have been used as emergency or famine foods in different parts of West Africa. The thickened rhizome of *Stylochiton Warneckei*, for example, is eaten in bad times after repeated washings in the lye of ashes. The rhizomes of *Anchomanes difformis*, in addition to being given repeated soakings and similar washings with ashes, are boiled for a prolonged period. Sometimes they are cut up, allowed to ferment in a pot for several days, then sun-dried and stored. As in other aroids, the irritating properties are due to saponins and raphides. They are also used in famine times on the Gold Coast, and in Lagos markets the large wild tubers are sold mainly for medicinal purposes, though also as emergency food under the safeguards necessary for other aroids. The large corms of *Amorphophallus dracontioides* are also very acrid because of their saponin content, but in times of famine they have been cut up, repeatedly washed and then boiled for a day or two before being eaten. The tuber of another species, *A. aphyllus*, is eaten in times of scarcity in West Sudan by the Wolofs of the Cayor region, who first dry and then boil them to remove the acridity. *A. campanulatus* is cultivated in India at Gujarat

and Baroda where its care is so costly as to be undertaken only by the well-to-do. Its tubers are usually planted out in May or June, and are fit for digging 12 months later, each tuber weighing two to ten pounds if properly cultivated. These corms are boiled like potatoes, cooked in curries, pickled or preserved, and when gathered wild are a common article of food among the poor. A yellow dye is obtained from *Cochlospermum tinctorum* and is used to color Shea butter and to color or even flavour the oil in which food is cooked.

The sedges (Cyperaceae) produce some minor human foods. The underground stems of *Cyperus esculentus*, the tiger nut, are frequently sold in Gold Coast markets for chewing and for preparing white jelly-like " tiger-nut milk ", and have also been used as famine food. And the slightly fragrant tubers of *C. rotundus* are gathered and chewed by herdsmen and boys. Two other members of the Cyperaceae have edible underground parts, namely, *Kyllinga erecta* with aromatic and rather bitter rhizomes, sometimes used to flavour cooked foods, and *Mariscus umbellatus*. In the 1897–1899 famines in India many unusual forms of foods were devoured, such as the minute tubers of certain sedges sifted out of the soil on the edges of dried ponds. The rhizomes of the root parasite *Thonningia* are used in soup or as a spice by the Hausas of northern Nigeria. The roots of a shrub (*Carissa edulis*) are sometimes added to soups or stews to give them an agreeable flavour, or to meat or fish to disguise an odour. In the Gold Coast they are also chewed and the juice swallowed as a tonic, or the roots used as " bitters ". Scott Elliot describes the preparation of a beverage from the roots of three wild plants of the genera *Combretum, Dissotis* and *Hippocratea*.

In addition to the foregoing, famine usage has been made of the corms and fruits of *Zygotritonia crocea* (Iridaceae) in French Guinea, and of the rhizomes of cat tail, *Typha australis*. And finally there are references in the literature to emergency foods in Africa which have not been identified. Among these are the pignuts which are consumed by the Herero (Damara) of South West Africa but which are so worthless nutritionally and so indigestible that they must be eaten in excessive quantities to sustain life. Various unpalatable and unidentified tubers are eaten by the Bongo, and the Heusaquas sow a root called " dacha ", full of strong and pungent sap. If eaten or macerated in water and then drunk, it intoxicates like wine, to the point of promoting loss of reason. And finally the Hottentots have been recorded as chewing a root as a narcotic.

Bark

The bark of *Craterispermum cerinanthum* is said to be edible, and that of *Bridelia ferruginea* is sold in Yoruba markets (southern Nigeria) for the preparation of a mouthwash to cure thrush in children. A cold infusion of it, mixed with lime juice, or a combined infusion of both, is used in this way. The bark, leaves and roots are also used in the Yoruba agbo pot for children. In some regions the bark of *B. micrantha* serves as a substitute mouthwash, and in Liberia that of *Napoleona leonensis* is occasionally eaten, chopped up with kola or mixed with rice. The barks of two capparids, *Boscia angustifolia* and *Cadaba farinosa*, are eaten with cereals. The inner and fibrous bark of a certain fig tree (*Ficus ovata*) is sweet and can be chewed like cola; and a palatable beverage, given even to newborn babies, is made as a cold infusion from the bark of *Anogeissus Schimperi*. The bark of a shrub, *Grewia mollis*, is mucilaginous and is widely used in soup, or dried, pounded and mixed with bran meal and made into cakes by the Hausas. According to Watt, the bark of the baobab (*Adansonia*) is eaten in Senegal.

Pith

The Thonga of southern Africa make flour of the pith of certain palm trees in times of famine, and the Bushmen of that region eat the cores of certain aloes along with *Acacia* gum and various bulbs, roots and berries. The succulent interior of the nodes of a grass, *Aristida stipoides,* is eaten by boys in northern Nigeria, and the sweet marrow in immature spikes of *Typha australis,* known in Hausa as " laka ", is eaten in Bornu (North Nigeria) along with a local variety of salt known there as " manda ".

Buds

The tender terminal buds of palm trees are popularly known as " palm cabbages ", and those of most West African palm trees are eaten as vegetables, either raw or cooked. Since each " cabbage " is the only bud on a tree, its removal results in the death of the tree. Such terminal buds of *Borassus* palms are used as a food, supposedly possessing medicinal properties, while those of a rattan palm (*Calamus deeratus*) are said to be eaten by the Mendes of Sierra Leone. Also edible are buds of the oil palm (*Elaeis guineensis*) and coconut palm (*Cocos nucifera*), as well as those of the dum or gingerbread palm (*Hyphaene thebaica*), and of the dwarf date palm (*Phoenix reclinata*) and of a rattan palm (*Ancistrophyllum secundiflorum*).

Gums

Refined gum from several African species of *Acacia,* particularly *A. Senegal,* have long been used in the confectionery trade, in both America and Britain, and some of these same gums as well as others have been similarly utilised, but without refinement, by both African natives and Australian aborigines. Among the Dinka, for instance, in the absence of milk and grain, nourishment is reported to be derived from gums of the forest as well as from wild roots and fruits; and the Masai women have been observed to chew a frankincense-like gum, though it was not clear whether it was chewed for its own sake or as a preliminary to mending gourds with it. Gum oozing from holes made in tree trunks by certain beetles has also been reported as being collected and eaten. More specifically, the common Savannah tree (*Anogeissus Schimperi*) provides a viscid but not very soluble gum which can be used as a substitute for Senegal gum and is eaten in North Nigeria and East Sudan. The soft and juicy fresh gum of the desert date (*Balanites*) is pleasant to suck. The exudation of *Sterculia setigera* is used by some tribes in the West Sudan in food in place of baobab leaf where the latter is unobtainable. This tragacanth-like gum, yielded more abundantly by trees along river banks than by those on drier areas, is known in the East Sudan as " da " or " kandi gum " and is similar to that of *S. cinerea*. *Lannea acida* is also said to yield an edible gum. The Bushmen of southern Africa, as well as African children elsewhere, are reported to eat *Acacia* gum; that of *A. campylacantha* is reputedly of agreeable quality and is sometimes sucked; while that of *A. Seyal,* though inferior to the gum of *A. Senegal* (the true gum arabic), is edible when fresh. *A. macrostachya* also yields an edible gum in North Nigeria.

Sap and Latex

The white latex of Sodom apple (*Calotropis procera*) is used by Fulani to curdle their milk, whereas certain pagan tribes of East Sudan ferment their corn beer with it. Watt describes a similar use of it as an auxiliary to alcoholic fermentation. Wine is prepared by fermentation of the sap of so many kinds of palm that to discuss them in this article beyond mere mention here is impractical. Among dicotyledons a clear and potable water is obtained from the cut stems of *Tetracera potatoria,*

and the stem of *Sterculia setigera* in savannah regions also provides a refreshing liquid in times of drought. The juice of an asclepiad (*Gymnema sylvestre*) shares with the miraculous berry the power of destroying the sense of taste for sweetness and bitterness.

Stems

The young shoots of balsam spurge (*Euphorbia balsamifera*) are often cooked in food in Senegal, as are also the young shoots and fruits of *Hymenocardia acida*. Use of *Borassus* buds has been noted, and sometimes tender centres of these palms when immature are used as famine food, as are the young stems of papaya (*Carica Papaya*) in the East Indies. The young stems of the grass *Echinochloa stagnina* are sucked for the sweet juice in them, and sugar actually extracted from the culms is utilised in the making of sweetmeats and of a liquor drunk by the Mohammedans, fermented or unfermented, though a state of non-fermentation is probably impossible to maintain. *Ancistrophyllum secundiflorum*, a rattan palm, produces young shoots which, after being boiled to remove their bitterness and fried in butter, resemble endive and are eaten as such. An unusual usage is that of the stems of an asclepiad (*Pergularia tomentosa*) which in certain semi-desert regions are soaked in warm milk, then used as a starter in cheesemaking. A wild edible form of *Asparagus* (*A. Pauli-Guilelmi*) occurs in the West African flora and resembles the commercial plant (*A. officinalis*) in general appearance. Its tubers can be boiled and eaten. Chevalier states that the former reaches a larger size near ant hills and can be considerably improved if grown in good soil, when thicker and more succulent stems can be produced, as compared with its straggly and spiny nature in the wild. When asparagus is not available, the white shoots of germinating baobab seeds, or of young shoots of papaw, sometimes serve as substitutes. A shrub called bitter leaf (*Vernonia amygdalina*) is often specially grown in compounds for its young twigs which are chewed as a stomachic tonic and appetiser. Finally it is fitting to mention that young shoots of various species of bamboo have formed an important article of food in India where, freed from sheath and hairs, they are cut up into small pieces and eaten in curries, whereas shoots of smaller species when boiled with a little salt are usable as an inferior form of asparagus. Watt believed that the flowering of bamboos, which is a well-known irregular periodic phenomenon, is influenced by the same factors that bring about famine. He was also of the opinion that this correlation accounted for the providential supply of food from this source to save the lives of thousands of persons during several of the great famines of India.

Leaves

There are in West Africa at least 150 species of plants, of which the leaves are used as food. Of these, over 30 are cultivated, 25 or more are semi-cultivated, and the remaining 100 are wild. As elsewhere, leaves are nutritious in supplying vitamins and minerals. As a rule, there is not much difficulty in their collection, since a number of herbaceous species occur as weeds on farms, and, though in times of famine they tend to wither and die, the woody species are much more persistent and offer a constant supply of food. Certain species, however, may be used as food in one part of West Africa but not in another, while others, though widely used as food elsewhere in the tropics, are not so used in West Africa at all, even in time of famine.

The African is a great eater of vegetables, and a glance at the list of plants which he utilises for their leaves will show how varied his taste is. He even takes the trouble to soak the leaves of

sea purslane (*Sesuvium Portulacastrum*) before use in order to remove the salt, while the leaves of a rattan palm (*Ancistrophyllum secundiflorum*) and of an aroid (*Stylochiton Warneckei*) have first to be boiled to remove the bitterness; the former is then fried in butter and resembles endive in taste, and the latter is later cooked with Asben salt which is prepared locally. The Kanuris of North East Nigeria, however, actually appreciate the balsam apple (*Momordica Balsamina*) for its bitter taste after cooking. Salt is prepared by burning various plants in West Africa. Plants used in this manner occur naturally more in the inland areas, for instance, around Lake Chad, and such vegetable salts tend to be richer in potassium than in sodium salt.

The main use of leaves is as vegetables in stews and soups which are much consumed by West Africans. The agbo pot of the Yorubas, for instance, is a concoction of various wild and cultivated leaves, vegetables and the like, and is fed specially to children. The ingredients of the pot evidently supply certain necessary food constituents, such as minerals and vitamins, and are also probably somewhat laxative in action. Other plants cooked together include *Tribulus terrestris* with *Cassia Tora*, and *Urera Mannii* with *Fleurya*.

Dried leaves are widely used as condiments and flavourings for sauces and cereals, sometimes after boiling, sometimes after pounding or drying. The best known of these is baobab (*Adansonia*), of which the leaves can be used as condiment, seasoner, as spinach and as a soup vegetable. Its sun-dried leaves are rich in calcium, containing 3.64% calcium oxide, and also potassium acid tartrate, common salt and tannin. Tea substitutes are provided by the Gambian tea bush (*Lippia adoensis*) which is appreciated by Europeans and Africans alike, and by the bush tea-bush (*Hyptis suaveolens*) which provides a mint-flavoured variety. While on the subject of beverages, it might be interesting to mention that the leaves of *Napoleona* spp. when added to palm wine, keep it fresh for three or four days.

Raw leaves are used in salads, one plant (*Salvadora persica*) having a pungent cress-like taste when chewed, and young shoots are taken from some species, such as the "palm cabbages" already mentioned.

It is likely that research on wild food plants used in human consumption would show that a number of the plants would be unsuitable for developing as crop plants, but they might be used in feeding domestic stock. In parts of West Africa, for example, domestic animals are gravely neglected, usually picking up whatever scraps they can from the streets and courtyards of houses. With increase of transport, the trend towards the towns, and the increasing land shortage, the enclosing of animals and the fencing-in of farms is bound to come gradually, and new fodder plants might be discovered and developed from these emergency human food plants. There are 26 species of edible leaves eaten by West Africans which are also used by them for feeding their domestic stock, including ostriches and silkworms, seven being fed to horses, three to sheep, three to goats, one to pigs, and seven others are in general use as fodder for animals. A close study of the food plants of the wild pigs of West Africa, of which there are several species, would bear some relation to the food not only of man but also of his domestic animals, and a similar study of the plants eaten, for example, by antelopes might bear some relation to the present and future food plants of cattle. It should be remembered that domestic animals are not used as food so much as in Europe or the United States, nor on the whole are milk and milk products. Therefore the development of animal husbandry in

West Africa is a very important matter in considering the general food problem and needs of that area.

Flowers

Flowers are seldom used as a staple article of food, though some of the large and more fleshy ones are eaten alone. Among cultivated plants are those of the introduced clove (*Eugenia caryophyllata*) and of two species of *Hibiscus*, namely the corolla of okra (*H. esculentus*) and the fleshy calyxes of red sorrel or roselle (*H. Sabdariffa*), which are eaten either fresh or dried. Pumpkin flowers (*Cucurbita Pepo* and *C. maxima*) are also used as potherbs in West Africa. Flowers of *Grewia mollis* are sucked by children as well as eaten in soup, like those of the desert date (*Balanites*), or used as a sauce vegetable. Those of *Balanites* are boiled and added to daudawa, a Hausa food prepared from *Parkia*, salt and pepper being added and then the whole eaten ceremoniously.

The flowers of several wild leguminous plants (*e.g., Crotalaria glauca*) are eaten. Those of *Tamarindus* are occasionally made into a kind of salad; a number of *Acacia* flowers, along with *Acacia* gum, are eaten by children; the flowers of the wild and sometimes cultivated shrub, Egyptian sesban (*Sesbania aegyptiaca*), as well as the large and fleshy flowers of *S. grandiflora* are eaten; and those of the wild bean (*Sphenostylis Schweinfurthii*) make an excellent vegetable which is appreciated also by Europeans. The large fleshy brown calyxes of the red flowered silk cotton tree (*Bombax buonopozense*) are mucilaginous and are eaten in soup, or may be used as a sauce to replace that made from sorrel (*Hibiscus Sabdariffa*); some of the North Nigerian pagans make a sauce from the flowers of this tree.

The receptacles of the water lily flower (*Nymphaea Lotus*) are sometimes used as food. The blossoms of the asclepiad, *Leptadenia lancifolia*, are added to beans or may be used as a soup vegetable, as are those of an aloe (*A. Barteri*). Various other wild species with edible flowers are *Taccazea Barteri*, *T. nigritana* and *T. spiculata* var. *Benedicta*, whereas those of *Cocculus pendulus* (Menispermaceae) are added to food. The flowering tops of *Glossonema nubicum* and the fruits are eaten raw. The fragrant flowers of the spicy cedar (*Tylostemon Mannii*) are used to flavour rice and other foods, and those of *Anona senegalensis* are also used to flavour local foodstuffs. From the fragrant flowers of *Lecaniodiscus cupanioides* (Sapindaceae) an aromatic water is sometimes prepared, similar to that made in parts of the West Indies from the closely related and originally West African akee apple tree (*Blighia*). The central portion of the immature spike of the bulrush or cat's tail (*Typha australis*) is sweet and is eaten in Bornu (North Nigeria) with a kind of local salt. The edible flowers of a composite, Para or Brazil Cress (*Spilanthes Acmella*), contain an active principle, spilanthol, which has a local anaesthetic action.

Fruits

It has been said that fruits are the only plant food which can be used by man in an unchanged natural form, *i.e.*, that can be eaten raw before any of its constituent mineral salts and vitamins can be altered or lost by processing or cooking. The same is true to some extent of leaves used as raw salads. There are over 200 species of indigenous wild and cultivated plants bearing edible fruits and seeds in West Africa, most of which can be eaten raw. Cultivated fruits such as the banana, plantain, citrus, avocado, papaw, mango, pineapple, breadfruit, sweet and sour sop, do not come under the scope of this paper, as they are already well known and in wide use, and are not West African in

origin. Although Schweinfurth and other travellers have described how Africans, when clearing ground for new crops, often carefully preserve wild trees bearing edible fruits, little thought seems to be given to the cultivation of the indigenous fruit trees which grow easily and with little labour, though this category includes most of the best type of indigenous fruit-bearing plants, some of which are in the early stages of improvement. Such semi-cultivated trees as certain figs, the tamarind, baobab and cashew, and also certain gourds, come under this heading and provide extra nourishment in normal times.

In times of famine, when such annual crops would be scarce, man would instinctively seek wild fruits which, especially in seasons of drought, he would look for on shrubs, woody climbers, or trees, *i.e.*, on woody perennial plants. In severe famines when people might be suffering from actual starvation, the tendency would be rather to seek " roots " as a staple, since they provide bulk, augmented perhaps by wild grass seeds. Fruits would come in as an agreeable addition and a valuable aid against constipation. Experience teaches that a diet wholly of fruit is incapable of meeting all man's bodily needs. Many of the fruits used, in addition to those consumed on the spot, would be dried and stored, or oil extracted from them, especially from the seeds, as fruits are generally more abundant in certain seasons of the year; in times of severe drought some fruits would tend to become dried up and shrivelled, and thus less palatable; others would tend to fall to the ground and so be in danger of being lost. Animals too would suffer from famine conditions, so that competition between animals and man for wild fruits would be greater in times of famine.

The indigenous inhabitants of parts of South Africa followed the hedgehog (? porcupine) and baboon to discover the sources of food, refusing to taste any root or fruit which these animals did not eat. In various parts of the world (*e.g.*, South Africa, Australia) ants' nests have been robbed for the grass seeds collected there, which were then pounded and eaten. It would be interesting to know how much man's knowledge of food plants has been learned from animals; the study of food plants of wild pigs might be useful in this connection, as they eat starchy roots and fruits, and it is a well-known fact that the pig is the domestic animal whose diet and digestive apparatus is most closely related to that of man. A small point of interest in this connection might be the fact that the fruits of a tree (*Ochrocarpus africanus*) containing an acid yellowish pulp, which is eaten by humans, is also noted to be relished by snails (*Achatina*) which in turn are themselves edible.

Wild fruits are mostly eaten raw but are also prepared for consumption in many different ways, mainly by cooking, drying or in various fruit products. Of the many raw fruits eaten, perhaps the most interesting and useful are those of the tamarind which is not so fully used in West Africa as in India, though it was originally introduced from Africa to Asia. The tamarind, being a dry zone tree, would probably endure under famine and drought conditions. It occurs wild in the savannah regions of West Africa and is semi-cultivated on farms or even specially grown in villages or compounds. In Senegal the unripe fruits are made into a sweetmeat called " bengal " and are also used as a laxative and as a remedy for fever. The Nankanis of the Northern Territories of the Gold Coast use a bitter infusion of the pods in cooking cereals. The pulp surrounding the seeds is infused with sugar and honey for some days till mature and makes a pleasantly acid drink, to which onions are sometimes added. The fruit pulp together with the seeds is often seen in markets and is usable as

food without special preparation. It is sometimes eaten to relieve thirst on a journey, its acid flavour being due to tartaric acid, averaging about 9% potassium bitartrate, and some malic acid. Its use as an antiscorbutic, like lemon juice, has long been known in India, although it contains no citric acid.

The fruits of the dum or desert palm (*Hyphaene thebaica*) exist in different forms, some being inedible, others having a rind which tastes like gingerbread. These fruits form an important article of food in the drier regions, as on the dry banks of Lake Rudolf in East Africa, where the Turkana tribe subsists almost wholly on these fruits and the fish of the lake. The sweet fruit pulp of the jujube tree (*Zizyphus Jujuba*) (described by Mungo Park as "*Rhamnus Lotus*") provides, when fermented, a king of gingerbread which is used as food throughout West Sudan; this and the soft mealy pulp of the fruits of Christ's Thorn (*Z. Spina-Christi*) may have formed the "lotus" of the ancient Libyan Lotophagi (Lotus eaters) mentioned by Pliny, according to Burkill who considers that the Romans confused *Zizyphus* with *Celtis*, as both trees occurred together in Tunisia.

Many fruits bear names reminiscent of those in the western world because of their resemblance to them. The fruits of *Sorindeia juglandifolia* are called "damsons" in Sierra Leone, those of *Uapaca esculenta* "medlars" and those of *Antrocaryon Micraster* and *Spondias Monbin* "plums". The latter are said to cause dysentery if eaten in excess, while the bush mango (*Cordyla africana*) causes vertigo, and the strawberry-like many-seeded fruits of the negro peach (*Sarcocephalus esculentus*) tend to be emetic. On the other hand, the purplish fruits of the shrub *Carissa edulis* are put into the food of sick persons as an inducement to eat, the Twi name of the plant meaning "the fowl will be eaten up", while the translation of the Hausa name for the yellow sweet fruits of wild custard apple (*Anona senegalensis*) is "sustenance of orphans".

Of the fruits requiring previous preparation, those of the gourd family (Cucurbitaceae) are widely used, among them being the West Indian gherkin or wild cucumber (*Cucumis Anguria*), abundant near Thiès in Senegal, which are pickled in the green state, though edible when ripe. Young and tender fruits of some forms of the bottle gourd (*Lagenaria vulgaris*) are occasionally mixed with common cereals, though they are usually too bitter to be eaten. Another "gourd" (*Luffa acutangula*) is commonly cultivated in tropical countries for the immature fruits which are either boiled and eaten as a vegetable or used in curries. Forms of this plant having both bitter (poisonous) and sweet (edible) fruits are said to exist. These fruits are highly esteemed as a vegetable in India and are sometimes eaten on the Gold Coast in the immature state. Fruits of the common loofah (*Luffa cylindrica*) are cooked when young and eaten by the Hausas of North Nigeria. Though the wild fruits are generally bitter and even poisonous, an edible cultivated form has been developed in India and other countries; and the Susus of the coastal areas of French Guinea cultivate a striped and edible form. The tender fruits and shoots of the balsam pear or African cucumber (*Momordica Charantia*) are sometimes boiled and eaten with meat. Dried fruits are probably the most useful in times of famine because of their ability to remain edible after storage.

There is a considerable number of wild fruits of inferior quality, eaten in times of scarcity, reports of which frequently state that "the thin pulp is edible" or that "the fruits are said to be edible". Records of a number of others simply state that the fruit is edible, and no particulars about its qual-

ity or method of use are given, though further research will undoubtedly show some of them to be of worthwhile quality. In the meantime, however, they have been placed in this lowest category of edible fruits until there is evidence of greater value. Nearly all appear to be eaten raw.

Seeds

Most of the common plants cultivated for their seeds in West Africa, such as groundnuts, cocoa, breadnut and coconut, were originally introduced to the country, but many of them also grow wild and might escape certain famine conditions to be of use at such times. Interesting among these are the cashew nut (*Anacardium occidentale*), the capsicum peppers and the common or garden cress (*Lepidium sativum*). *Anacardium occidentale*, despite its specific name, is of oriental origin, though it has probably been in West Africa for centuries. It is sometimes specially cultivated, for instance near Lagos, but is more often semi-cultivated or even wild, though the fruits and seeds, particularly the latter, are collected from most of the trees, whether cultivated or not. The curious kidney-shaped " beans ", appearing as an appendage to the reddish fruits, are oily and are roasted, though the seed coat can stain indelibly when heated. 40–57% of clear pale-yellow pleasant-tasting oil can be obtained from the seeds. The roasted " nuts ", so common in Europe and America as almond-like cashews used in confectionery, are also appreciated for that purpose in West Africa, and though not yet exported, they appear in local markets. The seeds are sometimes boiled in soup. Of the peppers, *Capsicum annuum* and *C. frutescens* mainly, but also other species occasionally planted, are of tropical American origin, though now naturalised and widely used in West Africa. The small-fruited shrubby or bird pepper (*C. frutescens*) has the active principle, capsicine, in flesh, seeds and placenta, whereas in the wild or sweet pepper (*C. annuum*) it is mainly absent from the flesh. The common or garden cress (*Lepidium sativum*) is widely cultivated in the Old World, where it is often a weed. In North Nigeria it is grown along with onions under irrigation. The seeds are faintly spicy-pungent, become mucilaginous when soaked in water, and are sold in markets in small coherent ball-like masses, as red, white or black varieties. The plant is probably a native of Abyssinia, where an oil is obtained from the seeds. The seeds contain 50–60% of fatty oil and an enzyme, myrosin, which along with water yields a volatile oil, of which the principal constituent is phenylacetic acid, nitrile or benzyl cyanide. The seeds also have medicinal properties. The wild form (var. *silvestre*) is distributed from Anglo-Egyptian Sudan to the Himalayas, whereas the cultivated form (var. *vulgare*) with larger fruits and seeds often occurs as an escape in West Africa, though Dalziel never states whether it occurs wild.

Semi-cultivated plants grown for their edible seeds can almost be classed as crop plants. In some parts of West Africa they occur only wild, though in other parts they are definitely cultivated; others again are grown specially in villages or on farms, or both. Of the former, two are specially cultivated in certain areas. The first is the water chestnut or caltrop (*Trapa bispinosa*) which, though its use as a food plant is encouraged, is actually cultivated in pools by the Fulani in Adamawa Province (North East Nigeria) and by North Nigerian pagans. The second is a species of gingelly or benniseed (*Sesamum alatum*) occurring commonly around certain villages in the drier areas, but said to be specially cultivated in East Sudan. The closely related plant, *Ceratotheca sesamoides*, is sometimes cultivated in the Northern Territories of the Gold

Coast under the name " bungu ". Its seeds are rich in oil (37.7%) and are eaten in soup, together with the leaves. The seeds are also used to adulterate benniseed (*Sesamum*). Among the wild plants which are grown in village compounds or farms, the gourd family provides *Cucumis Melo* var. *agrestis* in parts of Senegal, French Sudan and North Nigeria. The seeds, after drying and crushing, can be used as food; in East Sudan they are eaten raw. They are sometimes exported as an oil seed from the latter district, and fermented cakes similar to those of daudawa from *Parkia* are made from them by the Hausas of North Nigeria. The bottle gourd (*Lagenaria vulgaris*) is another semi-cultivated gourd which is sometimes grown in villages mainly for use of its fruits as utensils, but also for its seeds which are commonly used as a masticatory, and some forms for oil used in cooking. The kernels contain, according to variety, from 40–50% of a clear oil and 5% of protein. The watermelon (*Citrullus vulgaris*) is another gourd, of which not only the fruit is eaten but the oily seeds used as food, being frequently sold in markets for that purpose, either eaten raw or ground up and used in soup like groundnuts. In South Tropical Africa (Kalahari) the seeds are also used to make a kind of porridge, and in West Africa they are sometimes roasted and used as a substitute for coffee. Another plant often seen in cultivation in villages and on sale in markets is the desert date (*Balanites aegyptiaca*) which has many uses, both the fruits and seeds being edible. The seeds are sometimes spread on roofs to dry before use as food; they are oily (40%) and form the diet of people living in the Shari and Chad area (Daggash). Sometimes they are steeped for three or four days before being eaten. In East Bornu (North East Nigeria) the Shuwa Arabs use the seeds in soup, whereas they are made into a kind of bread in Bagirmi, and have been made into a temporary food for slave gangs in East Sudan.

Besides the plants cultivated and semi-cultivated for their seeds, there are also many wild seeds of good quality which are eaten raw or prepared in many different ways, such as dried, fermented, cooked (by boiling, roasting and baking) and pounded. Oil is obtained from them, and the foods made from seeds include soup, porridge, cakes, sauces, flavouring condiments and coffee substitutes. Probably the best known of these are the cassias. Negro coffee (*Cassia occidentalis*) is widely known as a coffee substitute. Roasting the seeds destroys the purgative principle present, and they can be roasted and ground, and mixed with two or three times their own weight of real coffee. This substitute can even be used alone and is said to have febrifugal or stomachic properties and a strengthening effect. It contains no caffeine. The seeds of foetid cassia (*C. Tora*), roasted and ground, have also been used as a coffee substitute. In times of scarcity they have been eaten by the Moors. The rather acrid and scarcely edible fruits of *Zizyphus mucronata* have occasionally been roasted and used like coffee. The seeds of *Feretia apodanthera* have been used in Abyssinia as a coffee substitute. Those of *Tricalysia coffeoides* have been roasted and ground to produce a coffee-like beverage which is, however, devoid of caffeine. The seeds of *Parkia biglobosa* have also been used as a substitute for coffee. In his unpublished notes, Dalziel gives two other plants as substitutes, namely, *Abutilon* spp., the seeds of which are also eaten by nomadic tribes, and the huge seeds of the leguminous climber *Entada gigas*. The roasted seeds of *Boscia senegalensis* are also sometimes used. Two wild species are suggested as being worth cultivating: *a*) *Coffea Maclaudii*, which is both wild and culti-

vated; Chevalier classifies it as one of the *robusta* group, and it is said to bear fruit only every second year, the fruits ripening in January; the seeds produce coffee of an agreeable flavour, resembling that of *C. excelsa* of Ubangi Shari; b) *Coffea brevipes,* a wild coffee occurring on Cameroon Mountain between 2,000 and 3,000 feet elevation and also near sea-level in French Cameroons, is closely related to *C. arabica* and *C. congensis,* and is suggested as worthy of trial as a source of coffee.

The line between wild seeds of good and of inferior quality is not always easy to draw, but where a record states only that a seed is used in times of famine, the assumption is that it is not used at more normal times, and that therefore its quality is not high. Edible wild grass seeds are counted in this group, as the labour involved in the collection and preparation of such tiny seeds for food would probably be undertaken only in times of real emergency. Incidentally, grass grains are included here under seeds though technically they are fruits (caryopsis); the pericarp surrounding the true seed consists, however, only of an outer scaly layer. The wild grass seeds can be made into bread, gruel, soup and beverages, and are also reported as unspecified foods.

Of the wild rices, one of the hardiest is *Oryza Barthii* which occurs as a weed in cultivated rice fields and if left would eventually smother the cultivated rice. Of itself is yields an edible grain usable in times of scarcity. It is so easily detached that the heads are collected in baskets or calabashes. The grain has a good taste and is sometimes sold in markets. The plant is perennial and has long thick rhizomes, by means of which it forms vast meadows in inundated areas, chiefly from Sokoto westwards; the rhizomes are eaten by warthogs. Another wild rice (*O. Stapfii*) occurs in the Gambia, where it is regarded as being the original form, for it is the species which eventually survives in neglected fields. Like those of *O. Barthii* its seeds also tend to be easily shed and are collected as food in bad times. It occurs in swampy parts and is used as food in East Bornu (North East Nigeria). It is probably a parent of *O. glaberrima,* both species having simple branches to the panicle and producing roots at the lower nodes. Barth reports that a kind of rice used in Bornu as a considerable part of the diet was said to grow wild in the southern provinces, presumably of Nigeria. He also reports that in Bagirmi rice occurs wild and is collected in quantity after the rains, when it grows in swamps and temporary ponds in the forest. Burkill doubts that wild rice could be a principal food anywhere, as the supply would not be enough to meet the demand. However, a similar use of wild rice as food is given from Kanem, where it forms the principal food. Burkill states that grains of wild rice are collected in India, where they are awned, thus making collection easy. Wild rices generally shatter, a disadvantage which man's selection has removed, and where this happens the grains probably lie on the soil with crossed awns by which they are picked up.

Collection of grass seeds other than rice is an indication of tremendous want, as the amount of labour involved must have a very small return. On the borders of the Sahara Desert certain people collect the seeds of *Panicum turgidum,* a stiff desert grass with smooth and solid stems, from the nests of harvesting ants, and use the seeds as food. The Nama of southern Africa systematically and regularly rob the stores of grass seeds collected by certain black ants. Other seeds stored by ants are similarly plundered by them. Cleansed of sand and stones in wooden boat-shaped troughs, the seeds are washed and ground to an

edible flour. Many other grasses are used in times of scarcity for foods requiring grain, and some of them, namely, *Panicum laetum* and *Saccolepis africana,* might well be either introduced into cultivation or improved by selection. They might also be used as fodder, for they are good for farm stock, particularly poultry. To begin with, the seeds would have to be collected, but gradually the plants might be introduced into cultivation as fodder, primarily for their seeds.

Fungi

There are not many reports of mushrooms being used by Africans for food, though the Bongo make use of a great variety, and in other parts they are made into sauces. They are not common in Ukamba, though certain species are sometimes eaten by children, and they are used as food in North Rhodesia. When discovered by the Lango, they are kept free from weeds but are not deliberately cultivated.

Volvaria volvacea (Bull. ex Fr.) Quel. and probably other West African species of *Volvaria* are fairly common on the Gold Coast. Like the paddy straw mushroom of the East, *V. esculenta* can be dried in the sun, stored indefinitely and revived by cooking and soaking in water. This latter fungus is imported, dried in tins, and is used in Chinese restaurants in London. *V. volvacea* grows on felled oil palm trunks, cut down for palm wine, on the soft tissues where they are tapped; and exhausted trunks are sometimes inoculated by rubbing a portion of the pileus over the apex, or putting it into a cut. In the Peki district (Togoland border) this mushroom is actually cultivated on low beds of cassava or cocoyam peelings in places sheltered laterally by bushes. A portion of the stipe is thrust into the heap. The natural humidity generally renders sprinkling unnecessary. The paddy straw mushroom of the East is grown on rectangular beds of paddy straw which are watered daily and produce commercial crops. According to Dalziel, edible mushrooms occur on the felled stumps of *Sterculia rhinopetala.*

An interesting example of human food of fungus origin is given by Gwynne-Vaughan and Barnes. The growth of fungi, *e.g., Puccinia caricis* on *Urtica parvifolia* and on one or two other species, causes hypertrophy and malformation (curling up) of the infected part, thereby stimulating storage of starch. So abundant is this starch that the hypertrophies are used as food by the Himalayans.

Ferns

Ferns, though used as important greens in Malaysia, are not much utilized in this way in either India or Africa. The bracken (*Pteris aquilina*) is one of the few plants growing wild both in Britain and in West Africa; it is in fact widely distributed throughout the world. In Sierra Leone the tips of its young fronds are collected and eaten as spinach. They have a distinctly sharp taste and are rather slimy and stringy, but otherwise quite edible. The young fronds are also eaten, prepared in various ways, in other subtropical and temperate countries as food for man and pigs. A kind of fern, known in South West Nigeria as " nyamauyo " (Efik), is used in the preparation of Dika bread or Gaboon chocolate from the seeds of *Irvingia gabonensis.*

Simmondsia or Jojoba—*A Problem in Economic Botany*[1]

This desert shrub of the American Southwest offers an unusual and as yet undeveloped source of a valuable liquid wax. The principal problem in its commercial exploitation is that of cultivating the plants.

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History

Among the herbarium specimens which he collected in China, Link (5) found a plant that he described in 1822 as *Buxus chinensis.* Twenty-two years later Nuttall (7) collected the same kind of plant near San Diego, California, and named it *Simmondsia californica.* Placing the plant in the genus *Buxus* was an error; *chinensis* was an error, too. Torrey (10), describing *Simmondsia,* mentioned that " Mr. Nuttall thinks that the genus is very clearly allied to *Garrya.* Lindley placed it without remark in Euphorbiaceae and we are inclined to follow him notwithstanding the absence of albumen ". At present the plant is known in botanical literature as *Simmondsia chinensis* (Link) Schneider of the family Buxaceae. Van Tieghem (11) proposed that a new family, Simmondsiaceae be created, containing one monospecific genus, *Simmondsia californica.*

Long before Link's discovery, *Simmondsia* was known to the natives of the Southwest. It grows in abundance in Arizona and in adjacent parts of Mexico, occupying an area roughly 700 miles long and 100 miles wide. Occasionally it occurs in southern California. The original Indian name was " hohohwi " (1). Transliterated into Spanish, " hohohwi " became " jojoba ". Clavijero (2), in his *Storia della California,* published in 1789, remarked that " La Jojoba é uno dei piú preziosi frutti della California ". He ascribed the most astounding medicinal qualities to the seed oil of jojoba and said that the oil was used by natives as a substitute for olive oil. Almost all the later and very numerous references to *Simmondsia* emphasize the unusual properties of its seeds, especially the fact that they are very rich in oil. The plant is dioecious; the female bushes bear seeds about the size of peanuts, which the Indians roast and use for food or boil in water to extract the oil. The plant itself is browsed by cattle, goats, sheep and deer.

At the beginning of the twentieth century the French Government became interested in *Simmondsia.* Some seed was planted in French North Africa and some experiments were made with the oil (12). Unfortunately the results of these experiments are not recorded. In 1907 Roehr (8) made some pharmaceutical tests of *Simmondsia* oil, but the results of her investigations, published in 1910, did not throw any light on the chemical composition of the oil. At

[1] Contribution from the California Forest and Range Experiment Station, which is maintained by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California, Berkeley, California. Photos by U. S. Forest Service.

about the same time the California Agricultural Experiment Station distributed *Simmondsia* seed among several cooperators (11). The northernmost plantation from this seed was near St. Helena, Calif. The writer was unable to find any further record of these early plantings of *Simmondsia* outside its natural range. Later *Simmondsia* was used as a hedge and an arboretum plant in Arizona and in some parks in Santa Barbara, San Marino and Los Angeles in southern California. Attempts have been made to introduce *Simmondsia* in Argentina (9) but apparently without much success. There have been reports that Germany began to import *Simmondsia* seed from Mexico in the late 1930's.

The persistent and numerous references to the medicinal and culinary use of *Simmondsia* seed oil prompted Greene and Foster (4) in 1933 to determine some of its physical and chemical constituents, such as specific gravity and saponification value. By comparing *Simmondsia* oil constituents with those of many other known vegetable and animal oils (fats), Greene and Foster arrived at the conclusion that *Simmondsia* seed oil differs radically from all known seed oils and that its characteristics are similar only to those of sperm whale oil which occupies a peculiar place among animal fats and oils. Chemically speaking, *Simmondsia* seed oil is not a fat but a liquid wax. Fats, including the seed oil of most plants, differ from waxes in being composed of a molecule of glycerine to which three molecules of various fatty acids are attached. On the other hand, waxes are composed of one molecule of a long-chain alcohol to which one molecule of a fatty acid is attached. The absence of glycerine in *Simmondsia* seed oil gave Greene and Foster further evidence that the oil is not a fat but a liquid wax.

TABLE I

PHYSICAL CONSTANTS OF *Simmondsia* SEED OIL

Item	Constant
Refractive index at 25°C.	1.4648
Specific gravity 25°/25°	0.8642
Iodine number (Hanus)	81.7
Saponification value	92.2
Acid value	0.32
Unsaponifiable matter, percent	48.3
Iodine number of unsaponifiable (Rosenmund-Kuhnhenn)	77.2
Acetyl value of unsaponifiable	171.8
Saturated acids (Bertram), percent*	1.64
Iodine number (Hanus)—total fatty acids	76.1
Neutralization value of total fatty acids	172.0
Glycerine	0.0

* It should be observed that no separation of the saturated acids could be effected by the lead-salt ether method.

TABLE II

CHEMICAL COMPOSITION OF *Simmondsia* SEED OIL

Component	Percent
Saturated acids	1.64
Palmitoleic acid	0.24
Oleic acid	0.66
Eicosanoic acid	30.30
Decosanoic acid	14.20
Eicosanol	14.60
Decosanol	33.70

Chemical and Physical Properties

This discovery aroused a great deal of interest among the vegetable oil chemists. From the laboratories of two outstanding authorities on vegetable oils, Hilditch (3) in England and Jamieson (6) in this country, almost simultaneously came reports on the results of chemical investigations of *Simmondsia* seed oil. These reports confirmed Greene's and Foster's findings and gave accurate data on the chemical composition of the oil. Tables I[2] and II[2] give

[2] Reproduced by permission of the Journal of American Oil Chemists' Society, formerly Oil and Soap.

Fig. 1 (*Upper*). *Simmondsia* (dark bushes) is an important food for range cattle on the southern slopes of Arizona mountains.

Fig. 2 (*Lower*). A young *Simmondsia* plantation at Riverside, Calif., five years old and ready for selection. Most of the staminate bushes were removed shortly after the picture was taken, leaving only a sufficient number to assure adequate pollination.

the physical constants and the chemical composition of *Simmondsia* seed oil as reported by McKinney and Jamieson (6).

As a result of their investigations, McKinney and Jamieson concluded that oil from the seed of *Simmondsia:* " . . . is not a glyceride fat but a liquid wax, composed almost entirely of esters of high molecular weight, mono-ethylenic acids and alcohols ".

" The unsaturated acids consist of a mixture of eicosanoic and decosanoic acids, along with small quantities of palmitoleic and oleic acids. The unsaturated alcohols are a mixture of eicosanol and decosanol, along with a little hexacosanol and a small quantity of alcohols of lower molecular weight. Its composition indicates that it is somewhat similar to sperm oil ".

" This oil, on account of its unique composition and properties, could probably be used for several different purposes. When heated to about 300° C. for a short time it becomes colorless. For some months two chemists have used it in place of sulphuric acid in their melting point apparatus. It would appear useful as an ingredient in prepared waxes, as a lubricant and for the treatment of leather. The sulphonated product might also have some industrial use ".

In 1938 the Bureau of Standards reported on a test of *Simmondsia* oil. Results of this test are given in Table III. The Bureau of Standards commented that: " The material is believed to have promising possibilities because of its high viscosity index and because of its high flash and fire points. The high pour point and neutralization number are unfavorable, but can be reduced by suitable refining ".

After the report by McKinney and Jamieson had been published, it became evident that *Simmondsia* seed oil offered to industry an entirely new product possessing certain qualities that could not

TABLE III

BUREAU OF STANDARDS REPORT ON TEST OF *Simmondsia* OIL, OCT. 28, 1938

Item	Constant
Flash Point (C.O.C.) °F	555
Fire Point (C.O.C.) °F	640
Viscosity S.U. at 100°F., Sec.	127
Viscosity Index (Dean & Davis)	173
Viscosity S.U. at 210°F., Sec.	48
Color No. (A.S.T.M.)	2
Corrosion at 212°F., copper strip	Nil
Pour point °F	50
Neutralization No.	0.57
Carbon residue, percent	0.01

be found in any other vegetable oil. *Simmondsia* seed oil does not become rancid; therefore it can be used in processes in which ordinary vegetable oils cause considerable trouble. Its viscosity does not change appreciably at high temperatures; therefore it can be used for lubricating high speed machinery operating at high temperatures. It is the source of two long-chain alcohols having 20 and 22 carbon atoms; these are invaluable for the preparation of detergents, wetting agents and modern lubricants.

Simmondsia oil, like many other vegetable oils, can be polymerized into a tacky rubbery mass, so-called factice. However, *Simmondsia* oil factice differs from ordinary vegetable oil factice in being soluble in various solvents, such as benzol or gasoline. This property would make it very valuable for the manufacture of rubber, chewing gum, varnishes or linoleum.

Simmondsia seed oil can easily be hydrogenated by a process similar to hydrogenation of, say, cottonseed oil in the preparation of modern shortening. Hydrogenated *Simmondsia* oil is a very hard crystalline wax, having a melting point only slightly lower than the hardest wax known—carnauba wax. *Simmondsia* wax is harder than any other wax on the market except carnauba. The hydrogenated *Simmondsia* wax can

be used in the preparation of polishing waxes, manufacture of carbon paper, waxing of fruit, impregation of paper containers for milk, and many other processes. It is said that even such an ancient industry as candlemaking for domestic and religious purposes would offer unlimited possibilities for *Simmondsia* wax. Incidentally, candles made from it give a very brilliant flame and do not smoke.

Hydrogenated *Simmondsia* wax is a sparkling crystalline substance of a snow-white appearance, as contrasted with the gray or chocolate colored carnauba or cadellilla waxes, which are contaminated with many impurities. Because of its purity, *Simmondsia* wax should not be used alone in preparation of polishes but should be mixed with some other substances that make it more plastic.

Simmondsia oil, being a vegetable oil of a pleasant smell, taste and consistency, would make an excellent salad oil (subject to pure food laws) for people who would like to enjoy a good rich salad but at the same time avoid fats. Of course, if taken in excess, *Simmondsia* oil will act as a mineral oil. An interesting thing about *Simmondsia* seed oil is that it cannot be digested by a human organism. The fat-splitting enzyme—lipase—will not hydrolyze *Simmondsia* oil because the latter is not a fat but a wax.[3]

The plant offers a source of domestic liquid wax similar to whale sperm oil. During World War II all supplies of sperm oil were placed under full priority control because it became necessary to use vessels engaged in the production of sperm oil for other purposes and because the lengthy ocean voyages to whaling areas were subject to the perils of the sea and of enemy action. It was declared at that time by the Director of Priorities, Office of Production Management, that no adequate substitutes were available for sperm oil. *Simmondsia* oil could be as important in defense production as sperm oil. Its most important uses are as a lubricant for breaking in motors, in making machine tools, in rifling guns and in operating machinery at high speed and high temperatures.

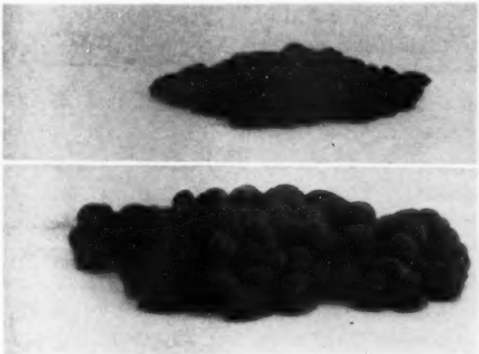

FIG. 3. *Simmondsia* seeds contain an unusual liquid wax possessing great possibilities for industrial utilization if they can be produced economically and in sufficient quantities. Each of these piles contains 100 seeds, the upper from wild bushes, the lower from cultivated plants.

Exploitation Possibilities

Here is a plant of a unique and very valuable nature, growing over an extensive area in California, Arizona and adjacent parts of Mexico. Many thousands of tons of seeds ripen and go to waste every year, but there is nobody to harvest them. The Indians of Arizona and Mexico gather only as much as they need for their own consumption—either as a roasted delicacy or for preparation of a reputedly hair-growing salve, but nobody is willing to collect the nuts as piñon pine nuts are collected; there is no ready market for *Simmondsia* nuts, and

[3] After submission of this article for publication the author's attention was drawn to the following summary of an article (Anales Inst. Modelo Clinica Medica 27: 803–818. 1947–1949): "Simmondsia liquid wax has an intense inhibitory action on tubercle bacilli. The virulent *Mycobacterium tuberculosus* put into contact with the wax does not grow in the usual cultural media".

the Indians do not want to harvest a product which has no commercial value. Moreover, gathering seeds from wild *Simmondsia* shrubs has other drawbacks. The shrubs are browsed very closely by cattle and deer, so most of the flowers are destroyed; rodents devour the seeds; the shrubs are scattered, and one-half of them are male, that is, they produce only pollen and no seed. The seed years are uncertain, and the seeds are small.

The possibility of developing a *Simmondsia* wax industry seems to hinge on the prospects of growing the bush under cultivation. Buying seeds collected from wild plants should be considered only as a subsidiary source of supply. When in a plantation, *Simmondsia* can be grown to a much larger size; an excess of male plants can be eliminated, leaving only enough of them to pollinate the female plants. The plantation can be easily protected from animals, and an easy (perhaps mechanized) method of harvesting could be developed.

In order to find out how wild *Simmondsia* would respond to domestication, a plantation was started in 1940 on the property of Mr. James G. Eddy at Riverside, California. The plantation has been taken care of by Edward Babcock and Sons, Agricultural Chemists, of Riverside, California. When the plantation was started, three seedlings were planted in each hill; five or six years later the plantation was thinned so that only one female plant was left in most of the hills; the surplus of male plants was removed, and only one male plant was left for every five female plants. At present (1951) the plantation is already in a productive stage, and the first crop of nuts was collected last year. The experience with this plantation has been invaluable. It showed, above all, that *Simmondsia* can be tamed. The plantation bushes grow under moderate irrigation and fertilization much better than in the wilderness. At present the bushes are more than eight feet tall, luxuriously green, and some of them produce more and bigger nuts than others. This opens an avenue for selecting better-producing specimens bearing larger nuts, and perhaps of a higher oil content, and thus developing a superior strain of *Simmondsia*.

It has been found that *Simmondsia* can be propagated vegetatively by cuttings and by grafting, so a better stock could be developed. Thus yield of nuts per acre of bushes and yield of oil per bushel of seeds may be considerably increased. There is a possibility of crossing *Simmondsia* plants from different localities of its range and thus developing better oil-yielding plants genetically.

To sum up, *Simmondsia* seed oil and its hydrogenated wax have properties of great value, but their commercial use seems to depend on cultivation of the shrub as an agricultural plant. In the author's mind there is no doubt that in the future *Simmondsia* will be considered as a very valuable cultivated plant of our Southwest and of adjacent parts of Mexico.

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Utilization Abstract

Antibiotics from Higher Plants. "Only a few antibiotics so far have been isolated from the higher plants in pure form", and none of them has passed the many tests necessary before an antibiotic can be regarded as a useful therapeutic agent. They have been found, however, in a great many plants. "Among them are the lotus, olive, laurel, myrtle, asphodel, and garlic, which were used as medicines in ancient Assyria; dates, figs, onions, lettuce, crocus, and opium, used as remedies by the Egyptians; the juices of celery, parsley, asparagus, peppers, and cabbage, favored as a medicine by Greeks and Romans; and amber, musk, manna, cloves, peppers, rhubarb, nutmeg, camphor, croton oil, and nux vomica, which the Arabians introduced and told their neighbors to take for aches and pains".

Apart from the few that have been isolated in pure form, antibiotics have been studied by extracting plant material with water, saline solution, dilute acid or alkali, or organic solvents, such as alcohol, acetone and ether, and then testing the extracts against standard strains of certain bacteria and fungi. In this manner, in one investigation of 2,300 species of plants in 166 families, 63 genera were found to contain inhibiting substances; in another, 22 of 120 species tested showed varying degrees of bacterial inhibition; and in a third investigation of more than 200 plants collected in Oregon, "many of them were found to contain substances that were bacteriostatic or bactericidal to micro-organisms in vitro, *i.e.*, in laboratory tests. Extracts prepared from five of the plants—buttercup, sagebrush, the mountain pasque, dwarf waterleaf, and juniper—were evaluated by many comprehensive tests in vivo, *i.e.*, in experimental animals, and by in vitro tests. Salt extracts of all five plants were found to have antibacterial and antimalarial activity in vitro. Two of the plants, sagebrush and dwarf waterleaf, contained substances that protected chickens during the blood phase of malaria, and an ether-insoluble, water-soluble fraction of a steam distillate of mountain pasque protected mice heavily infected with pneumococcus organisms. Extracts obtained from a species of sumac, *Rhus hirta*, showed marked bacteriostatic activity against Gram-negative bacteria but were less effective in inhibiting the growth of Gram-positive bacteria and fungi".

Several other investigations have been conducted elsewhere on the antibiotics of higher plants. A few of these substances have been given names, and the following plants have yielded them: wild touch-me-not (*Impatiens*), muskmelon (*Cucumis melo*), nasturtium (*Tropaeolum majus*), buttercup (*Ranunculus*), cabbage (*Brassica*), honeysuckle (*Lonicera tatarica*), crepis (*Crepis taraxacifolia*) (crepin), goat's beard (*Spiraea aruncus*), burdock (*Arctium minus*), ginger (*Asarum canadense*), garlic (*Allium sativum*), spotted knapweed (*Centaurea maculosa*), hops (*Humulus lupulus*) (lupulon and humulon), tomato (*Lycopersicum esculentum*) (tomatin), sweet potato (*Ipomoea Batatas*) and banana. (P. S. Schaffer, W. E. Scott and T. D. Fontaine, *U. S. Dept. Agr., Yearbook 1950–1951*).

Propagation of Strophanthus

Seeds and softwood cuttings have been found to offer rapid and reliable means of propagating this genus of tropical lianas, the seeds of which are a source of sarmentogenin that is convertible into the drug cortisone.

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The agricultural potentialities of *Strophanthus* as a source for the drug cortisone are still unknown, but, because of the possibility that it may have value for this purpose, a number of collections have been made and examined chemically. In most cases living vouchers of collections have been placed under propagation at the U. S. Plant Introduction Garden, Glenn Dale, Maryland, where techniques for rapid propagation from seed or cuttings are under study. Some preliminary data on seed germination and propagation methods employed may be of interest, should this genus prove worthy of agricultural development.

Since October, 1949, 155 introductions of *Strophanthus* have been received at Glenn Dale as seed, cuttings or rooted plants. They represent 24 species, all of African origin, which in their native habitats occur as woody lianas or clambering shrubs. All data obtained cover work done under glass, since *Strophanthus* is tropical in its requirements.

The seed of *Strophanthus* is not difficult to germinate. At temperatures of 72 to 75 degrees F. and humidity of 85%, almost complete germination can be expected from fresh seed. How long the seed will remain viable is not known at present, but tests at Glenn Dale show that when stored under calcium chloride at a temperature of 65 degrees F. the seed remains viable at least eight months. The following table indicates excellent germination generally obtained in most of the collections.

Sphagnum moss has been used exclusively as the germinating medium. Finely ground, the moss seedbed is prepared in metal flats and the seed scat-

GERMINATION DATA ON *Strophanthus sarmentosus* SEED

Plant introduction No. and origin	Date sown	Percent germination	Days to complete germination
187034	3-13-50	98	15
Gold Coast	11- 7-50	98	17
187035	3-13-50	98	15
Liberia	11- 7-50	100	17
187036	3-13-50	100	18
Liberia	11- 7-50	98	17
187037	3-13-50	100	15
Liberia	11- 7-50	98	17
187038	3-13-50	100	15
Gold Coast	11- 7-50	98	17
187039	3-13-50	100	15
Liberia	11- 7-50	100	17

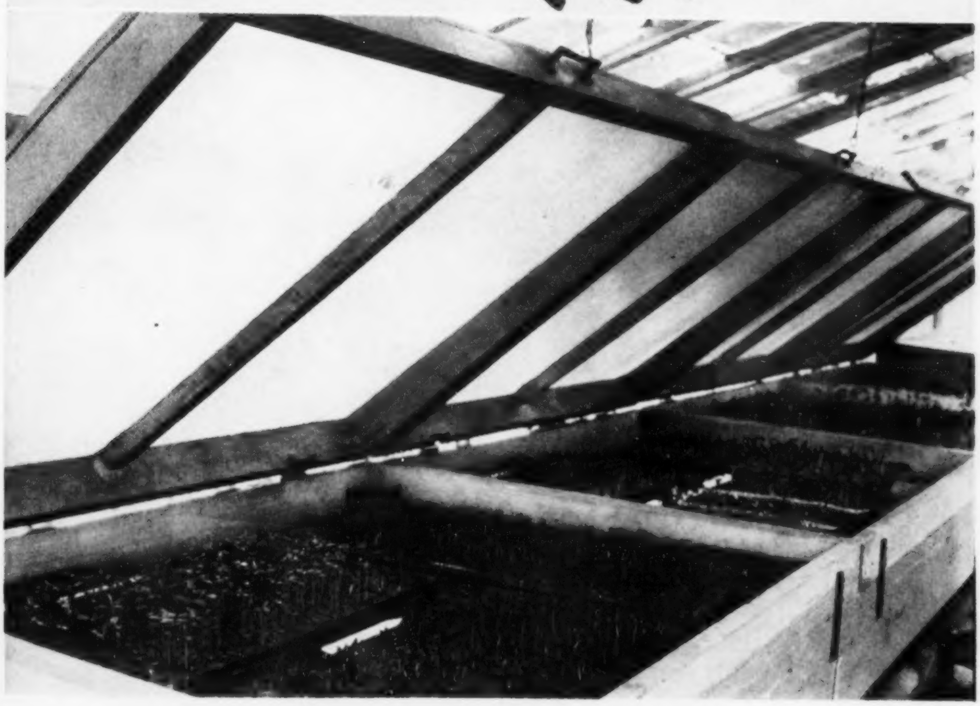
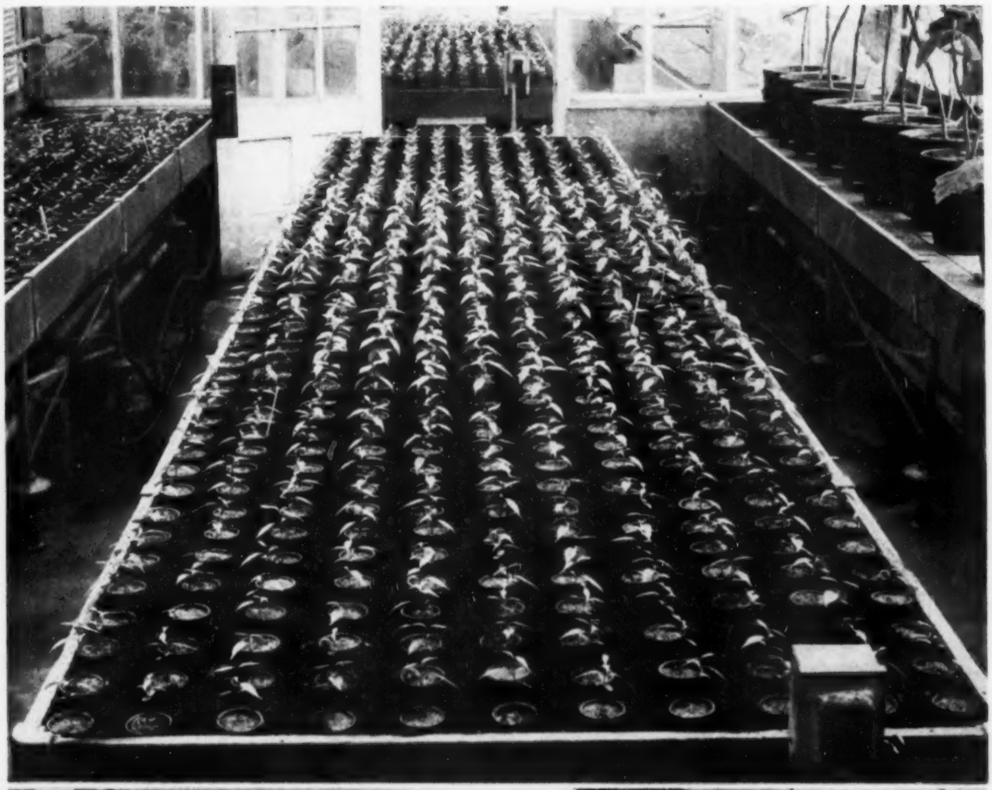


FIG. 1 (*Upper*). Seeds of a species of *Strophanthus* from Angola, southwestern Africa. Most of the nearly 50 species of *Strophanthus* have seeds that closely resemble those of this Angolan species.

FIG. 2 (*Lower*). Germinating *Strophanthus* introductions about 18 days after sowing. Note the use of metal flats and the portable propagating case.

FIG. 3 (*Upper*). Details of a flat of *Strophanthus* seedlings. The labels are written in India ink for permanency. This seed sown on 2–15–50 had completely germinated by 3–5–50.

FIG. 4 (*Lower*). Seedlings of *Strophanthus* transplanted while still in the cotyledon stage. The pots have been plunged in a sandbed at 78 degrees F.



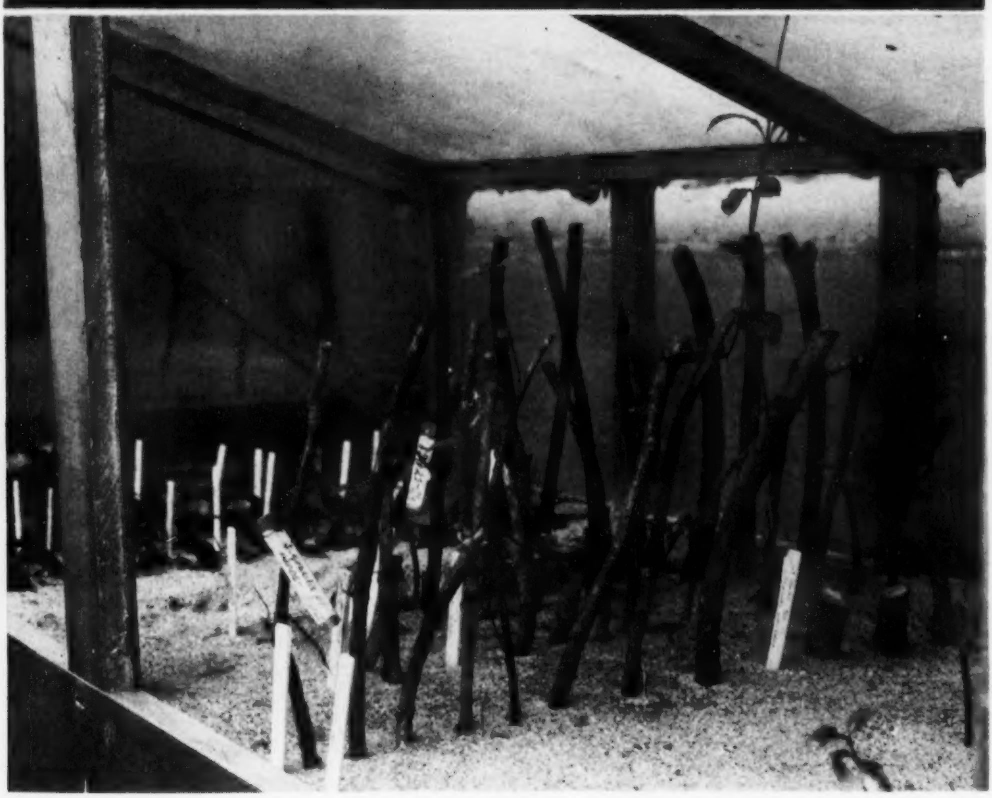


FIG. 5 (*Upper*). Potted seedlings of *Strophanthus* in the open greenhouse are plunged in peat moss or can be planted directly to a sphagnum moss bed.

FIG. 6 (*Lower*). Woody cuttings from Africa in sandbeds to force softwood shoots for propagating material.

FIG. 7 (*Upper*). The development of plants from cuttings: at left, the original material may die or produce softwood shoots used as cuttings; at center, softwood cuttings in the initial stages of rooting; at right, potted cuttings taken on 1–17–50 and rooted 100 percent on 2–8–50.

FIG. 8 (*Lower*). Seedlings of *S. eminii* showing the tubers formed.

tered on the surface without being covered. Once the seed has been sown, the flats are not watered again until all the seedlings have appeared. Germination, as the table shows, is completed in 15 to 18 days, and dead seed can be detected within 24 hours after sowing. Such seed disintegrates rapidly. Other than this type of loss, there have been no failures due to damping-off diseases or any irregularities in development of the seedlings.

Strophanthus seedlings can be transplanted while still in the cotyledon stage without loss, and either a normal potting soil or sphagnum moss can be used. Sphagnum is the most desirable when shipments of seedlings are to be made because the seedlings can remain in the original moss ball without disturbing the roots, while seedlings grown in soil must have the soil removed completely to comply with sanitary regulations. A seedling grown in sphagnum can be dropped without the rootball breaking and is therefore easier to handle. Because such high germination percentages have been obtained, not all seedlings have been transplanted but are being held in the sphagnum flats. It has already been demonstrated that seedlings of other plant material will exist untransplanted for as long as five years in sphagnum with little care and a very slow increment of growth. There is nothing unusual in the development of most *Strophanthus* seedlings. However, some species develop a tuberous taproot, and even in small seedlings this can be detected by rapid thickening of the base of the stem above ground. This has been observed in *Strophanthus gerardii* and *S. kombe*.

In addition to seed, unrooted woody cuttings and some small plants were received at the Garden. These have been more difficult to handle than seed introductions. In many instances the woody cuttings, sometimes one inch in diameter and several inches long, failed to root. They produced several small softwood shoots that were successfully used as cuttings, and the original sticks were finally discarded. The same is true of the rooted plants that were received. They became temporary sources of cutting material and eventually died.

The softwood cuttings rooted with comparative ease. When treated with IBA, 4 mg./gm. of talc, they rooted 100 percent in 38 days. Cuttings can be obtained from seedlings by the time they are six months old. Thus an introduction which at the outset produces few seedlings can be increased in number rapidly if necessary.

The following table shows the species and the number of introductions received and propagated since October 4, 1949. Determination of the species should be considered as tentative until their identity has been validated.

INTRODUCTIONS OF *Strophanthus* RECEIVED

Species	Seed introductions Received	Seed introductions Alive	Plants Received	Plants Alive
Strophanthus amboensis	1	1		
S. arnoldianus	2	1		
S. barteri	1	1	3	2
S. bovinii	1	1		
S. bullenianus	1	1	2	0
S. courmontii	2	2		
S. ecaudatus	1	1		
S. eminii	3	1		
S. gerardii	2	2		
S. gracilis			5	2
S. grandiflorus	2	2		
S. gratus	10	7	9	3
S. hispidus	8	7	11	7
S. hypoleucus	1	1		
S. intermedius	3	3		
S. kombe	2	2		
S. mirabilis	1	1		
S. nicholsonii	2	0		
S. petersianus	1	1		
S. preussii	4	4	9	3
S. sarmentosus	31	31	21	10
S. speciosus	1	1		
S. thollonii	1	1	1	1
S. welwitschii	2	2		
S. sp.	9	4	3	0

Utilization Abstract

Riboflavin. This substance, known also as " lactoflavin ", " vitamin B_2 " and " vitamin G ", is " widely distributed in food and feedstuffs but in amounts generally inadequate for high animal efficiency. High potency sources of the vitamin have been needed for enriching such foods and feeds. Today riboflavin is produced in quantity by chemical and fermentation processes. Small but nutritionally substantial amounts are incorporated in most bread flours and breakfast foods, in some pharmaceuticals, and in nearly all poultry and hog feeds ". It is commercially produced as a byproduct in alcohol, butanol and acetone fermentations, and as the primary product of fermentations based on the yeast *Ashbya gossypii*. (F. W. Tanner and V. F. Pfeifer, *U. S. Dept. Agr., Yearbook 1950–1951*).

May Rose. The blossoms of orange, jasmin and May rose, in the order named, are the three most important flowers of the world-famous perfume industry in Grasse, France, and the surrounding country. Cultivation of the May rose in this region is discussed in considerable detail in this article, and at one time 1,700 acres were devoted to its production; today only about 300 acres are devoted to it. " The perfumery rose has required a long selection of varieties in view of obtaining together the maximum of qualities: abundance of flowers and petals, rusticity, resistance to cold weather, diseases and insects, percentage and quality of essence. It is a hybrid of the Gallica and Centifolia rose-trees. The first originated in the Near East and was imported into France from Syria during the 13th century; the latter comes from Caucasus and has been known in France since more than three hundred years ". (Anon., *Am. Perf. & Ess. Oil Rev. 58(1): 43. 1951*).

Land Development and Large Scale Food Production in East Africa by the Overseas Food Corporation

The first attempt on a large scale to meet the increasing shortage of food in the world, by developing hitherto undeveloped areas, is being carried out in East Africa, with emphasis so far on two oil-crops—peanuts and sunflower seed.

A. H. BUNTING

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Editor's Note

In the January–March, 1949, issue of ECONOMIC BOTANY attention was directed to the very ambitious scheme of the British Government to meet the world shortage in vegetable oils by growing peanuts, or groundnuts, on a large scale in East Africa, and in the July–September, 1951, issue, attention was drawn to the abandonment of this scheme because its results had not been so great as had been expected. Newspaper and other reports have at times been very critical of this project, involving, as it has, many million of pounds sterling and not producing results commensurable with the cost involved. Like other great projects, however, this one perhaps is not to be judged by its immediate results but rather as providing the unavoidably expensive foundation for benefits to be derived far in the future. Such a viewpoint of this much discussed project is herewith presented by the Chief Scientific Officer of the Overseas Food Corporation, charged with the responsibility of executing that scheme.

Introduction and Historical Summary

The present large scale development of land for food production in Tanganyika has its origin in the world shortage of vegetable oils, in the post-war economic difficulties of Britain and in the urgent necessity to advance the development of the tropical regions of the world. Before World War II, Britain imported oilseeds and oil from many tropical lands. In particular some two million tons of oilseeds were obtained annually from India. Population advance and political development in that country, and the events of the war in the East Indies, abolished this exportable surplus and seriously reduced supplies from other producing areas.

In many ways the features of the edible oil shortage are similar to those of the general world shortage of foodstuffs of all kinds. Most of the world's food and a very considerable part of the food coming to world markets are produced by peasant farmers. The expansion or improvement of peasant production is, however, not a practicable solution to the problem, particularly on a short term view. Experience in all peasant countries shows that advances in peasant farming are difficult to achieve and almost impossible to maintain, unless decisive social changes accompany them, and that in the absence of strong incentives they are only very slowly evoked. The solution must include the development, on a very large scale, of new agricultural production.

A recent publication (5) has examined this question in some detail. The quantity of new farm land needed appears to be of the order of some hundreds of millions of acres, at least. The principal

soil and climate reserves of the human race, in which these vast areas are to be sought, are shown to lie in the podsol regions of Europe, Asia and North America, and in the tropical red earth and related zones in South America and Africa. Much of the African land reserve is in Northern Rhodesia, Tanganyika, Kenya, Uganda and the Sudan, under British political direction or influence. It was thus inevitable that Britain should seek in East and Central Africa the land needed for new oilseed production. Climatic considerations and shortage of labour rule out perennial oil crops, such as palm oil, as major crops in these areas, and direct attention to mechanisable annual oilseeds, of which the ground nut is clearly the most important.

The first proposals for the new development were made to the British Food Minister early in 1946 by the chairman of the United Africa Company (a member of the Unilever group) after a visit to East Africa. In July of the same year a mission was sent by the Minister to examine these proposals on the spot; it reported in October, and after examination the scheme proposed was accepted by the British Cabinet in November. The United Africa Company was asked to initiate the development until a state agency could be formed; it began preparations in December, and at the end of January, 1947, an advance party flew to Tanganyika to start operations. During 1947 the Overseas Food Corporation was established by the Overseas Resources Development Act, and assumed complete management of the East African Scheme on 1st April, 1948. The capital invested has been and still is drawn entirely from British Treasury sources.

The original plans of the mission are set out in a White Paper (11). They comprised the clearing of 107 agricultural "units" of 30,000 acres each (a total of 3,210,000 acres in all) in various parts of Tanganyika, Kenya and Northern Rhodesia, and the establishment on them of an agricultural system, in which two years of groundnuts would be followed in a four-year cycle by a two-year rest under grass. Other crops, including sunflower and sorghum, were suggested for inclusion in the system, and the capital cost was computed at £23,000,000. This expenditure has in fact been considerably exceeded, with only a small fraction of the original acreage developed. The areas selected were all uninhabited, or nearly so, for lack of dry season water supplies; they were all covered with thicket, savannah or woodland, and in some instances were infested with tsetse fly (*Glossina* spp.).

These ideas have, as was to be expected, undergone considerable modification. The latest plans for the future of the scheme, which represent a reduction of the final acreage to about 140,000 acres, are set out in a British Government White Paper (12). Experimental work has shown that several crops other than groundnuts are likely to be suited to large scale production and that more of the land than the 50% suggested by the mission can be devoted to cash cropping, provided soil-conserving measures are adopted. The development originally suggested in Northern Rhodesia has been abandoned on account of the distance of the area from a port and consequent transport difficulties, and for other reasons. The Kenya areas have been rejected on grounds of aridity and poor communications. Attention has been concentrated on three areas in Tanganyika, although some experimental work was conducted in Northern Rhodesia in 1948–1949. The "unit" concept has been replaced by a division of the land into farms averaging 2,000 acres each.

Central Province (Kongwa)

The Tanganyika areas are somewhat widely separated, being situated in the Central, Western and Southern Prov-

inces of the territory. Their soil and climatic conditions differ considerably. The Central Province area is based upon Kongwa, formerly a small trading centre about 200 miles from the coast at the southernmost end of the Tanganyika Masai plain. The main country rocks are gneisses of the Basement Complex. The elevation of the area is from 3,500 to 4,000 feet above sea level, and the cession range from yellow and brown to chocolate, grey and black in colour, and in texture from sandy loams to heavy cracking clays. Almost all these types are base-rich plain soils (9, 10). Their clay is predominantly kadinitric with metahallysite as the main constituent, and the mature types compact seriously on drying. The alluvial types do not compact, but crack on drying, although

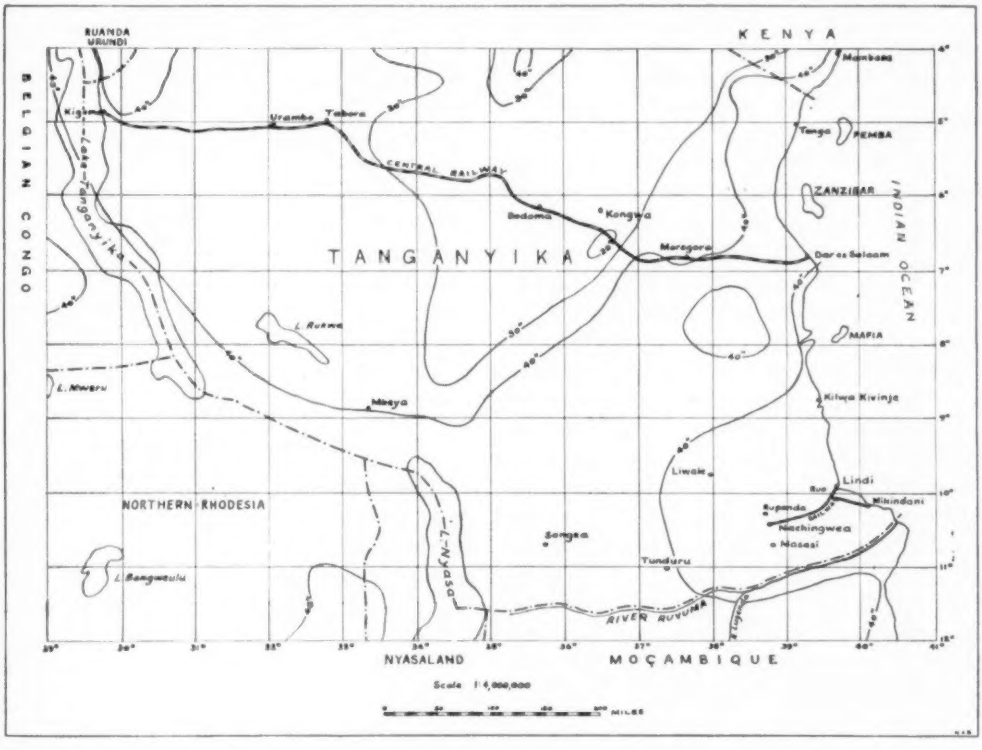

FIG. 1. Outline map of Southern Tanganyika and adjacent territories, showing isohyets and main localities.

rainfall, which occurs from December to April, with a more or less dry spell of two or more weeks at the end of January, appears to average about 20 inches annually.

The typical mature soils of the region are a pallid sand or sand with clay and a rich red sandy loam derived from granitic and hornblende gneisses respectively. The colluvial and alluvial soils derived from them in the catenary succession their clay mineralogy is not very different from that of the mature types.

The typical vegetation of the slopes and crests of the gentle rises is a dense impenetrable deciduous thicket 10 to 15 feet high in which *Commiphora* and *Grewia* spp. are important constituents. The wider valleys and the broad open beds of former lakes carry successional grasslands of various types.

The Kongwa area is undoubtedly mar-

ginal for arable production, in respect of rainfall. In the 1948–49 season, a dry one throughout East, Central and South Africa, the rainfall at Kongwa averaged 12 inches only and crop yields were extremely low. However, it has certain valuable advantages. The soils are relatively fertile, and the area is notably free of plant diseases. The future of agricultural production at Kongwa depends on the development of a dry farming system based on strict conservation of water by eliminating run off, the use of ban fallows in the rotation, avoiding moisture-wasting cultivation practices and reducing weed growth to a minimum. Field studies have indicated that significant quantities of moisture can be accumulated in the sub-soil on contoured land by ban fallowing, although no moisture accumulates under continuous cropping. Under standing *Commiphora* other spp. deciduous thicket all moisture is removed by transpiration, so that clearing of the thicket eliminates a major cause of wastage of moisture. The development at Kongwa has now been restricted to about 14,000 acres of arable land, but some attention is being given to cattle raising, and the arable average may be expanded in the future as the very difficult farming techniques needed in the Kongwa area come to be better understood. Country similar to that at Kongwa is widespread in Tanganyika, Northern Rhodesia, Kenya and the Sudan.

Western Province (Urambo)

The Western Province area is based on the railway station of Urambo on the Central Line railway about 60 miles west of the old Arab trading and slaving centre of Tabora and about 500 miles from the coast. The altitude is about 3,500 feet and the country is an ancient elevated Basement Complex peneplain, being part of the characteristic 3,500–4,000 foot plateau of Central Africa. The average annual rainfall is about 33 inches, falling mostly from December to May. The soil catena is typical of the extreme peneplanation. The mature type, a rich red loam, occupies the crests of the extremely gentle folds in the landscape, but about half of the area is composed of grey sands or of the complex layered sand and clay soils of the drainage depressions. Practically the whole area is covered by *Brachystegia-Isoberlinia* deciduous woodland or dry forest ("Miombo") of various types, except for the wider drainage depressions, which usually carry tall grass. The woodland is up to 60 feet high, and the canopy is rather open, so that a fairly dense growth of grass develops in the rainy season. This carries fierce fires through the woods in the dry season. In the Urambo region development is to cease at approximately 60,000 acres, but Western Tanganyika contains many thousands of square miles of similar country.

Southern Province

The large areas scheduled for development in the Southern Province were formerly very little known from the geographical or technical points of view. They lie at elevations of 1,000 to 2,000 feet above sea level, and their distance from the coast varies from 70 to 300 miles in the Lindi and Masasi districts.

In former times a Basement Complex peneplain was covered in this region by Karroo (? = Carboniferous) and Cretaceous deposits. Marine erosion, and subsequently river action, following a general rise in level, have since removed the Karroo and Cretaceous deposits over considerable areas. For the most part, the old Basement Complex land surface is once more exposed in these areas, although the confused history has left its mark in a somewhat complex soil pattern. Against the receding edge of the

Karroo plateau much material has been redeposited, giving a zone 15 to 20 miles wide of newer light coloured sediments, constituting in effect a separate formation, which has generated its own characteristic soils. (This exposition of the geology and geomorphology of the southern region is due to Dr. D. R. Grantham, Chief Geologist to the Overseas Food Corporation in Tanganyika).

The rainfall of the southern development area probably ranges from 30 to 40 inches, falling from November to April or May; and since in this region the southeast trade and northeast monsoon rainfall systems overlap, rainfall appears to be more reliable from year to year than in the other regions. Vegetation varies quite widely, but the principal formations are " miombo " of several types, which on the sediments below the Karroo plateau attains a considerable size, doubtless due to a combination of rather higher rainfall with ready permeability of the soil to water. In the more northerly parts of the region the peneplantation is so extreme that a large part of the superficial area is covered by grassland or grassland with scattered scrubby *Terminalia-Combretum* open woodland, in which *Sclerocarya* sp. and *Dalbergia melanoxylon* are frequent. Such areas are probably too low-lying for normal arable development but may be suited to pastoral development. The southern province development region will probably extend to 65,000 acres, on present plans. Many times this area is, however, available for further development.

In all this work Milne's classical unifying concept of the catena (8) is a continual source of guidance and illumination. Its applicability in a broad sense to tropical soil and vegetation complexes is very wide, although it breaks down occasionally in matters of detail or on sites of local geological diversity. Its overall value is, however, so great that it is today an indispensable part of the approach of all field workers in the tropics.

Order and Methods of Development

The order of development of the three regions was dictated by the urgency of the situation and the difficulties of communications and transport. It was imperative that a start should be made in 1947, and, although it was recognised, both by the original mission and by the Ministry of Food, that the Southern Province was the most promising area and that initial development there might be expected to yield higher immediate crop returns (on climatic grounds), the lack of port or railway facilities in the South made it inevitable that development should start in one of the two areas adjacent to the Central Line railway and served by the port of Dar es Salaam. The Kongwa region was the nearer to the sea, and a branch line of 16 miles only was needed to bring the railway into the area. It was accordingly decided to commence clearing at Kongwa, and the first bulldozer traces were cut on April 30, 1947. This decision, necessary and inevitable at the time, has meant that the organisational and operational methods have had to be developed in the least promising area, which consequently has now to carry an unduly large share of the capitalisation.

As a result of four and a half years experience, a sequence of development operations has been evolved; this is presented in a somewhat idealised form. The principles have been set down by Burlington (2) in more detail. The first stage is a rapid overall estimation of the possibilities of a proposed area, carried out by scientific, agricultural and survey staff. This is done by a combination of air and ground traverses, aided wherever

possible by the use of aerial photographs. The general nature of the terrain, soils, vegetation and communications is thus determined, and a decision in general terms is taken whether or not to develop the area.

If it is decided to develop, the second stage involves two main lines of work, detailed survey and logistic studies, including water investigation. Under the heading of logistics, communications and supply services are studied and developed, reorganised or improved. In the past, attempts have been made to proceed to land-clearing or other engineering work directly without close attention to this logistic work; the results have always been nugatory or even disastrous. This phase in the Southern Province of Tanganyika includes the construction of a new deepwater port and of 100 miles of railway, in addition to many miles of temporary and permanent roads.

At the same time, topographic, vegetation and soil survey is begun in detail. A rectangular grid of traces is cut mechanically at mile intervals in one direction and at quarter-mile intervals in the other. Levels are obtained by survey of the grid, while traverses of blocks, aided by air photographs, lead to a contoured soil and vegetation map. This is the basis for location and measurement of the land available for arable work, and from it is developed a unified land utilisation, communication, conservation and clearing programme.

Towards the end of the second stage, workshop facilities should be provided for the maintenance and repair of the heavy equipment deployed in the third stage. Neglect or underestimation of the importance of these facilities have not been rare in the Tanganyika development, and the consequence has always been disastrous.

The third stage is devoted to clearing, the construction of soil conservation works and civil engineering construction. The latter is concerned with water supplies, internal communications (external communications being ideally completed in Stage 2), temporary and permanent building of houses, stores, unit workshops, labour camps and the like.

Clearing Methods

Clearing is the biggest single task in the whole development. A detailed account of the methods used has been published (7). The larger trees are pulled over by a pair of heavy tractors moving on parallel lines about 50 feet apart and towing behind them a length of heavy and reinforced anchor chain, one end of which is attached to each tractor. The length of this chain must of course be such that the trees in falling forward do not come down upon the tractors. One or two additional tractors move behind the first pair, with tree-dozer equipment mounted on them, to assist the towing pair in the felling of larger or inconveniently formed trees. Felling is possible only in the wet season, when most of the trees can be pulled out of the ground complete with their stumps and larger lateral roots. If felling is attempted in the dry season many of the trees snap off and their stumps are subsequently difficult and costly to remove. This method is new to East Africa, but in its general lines it has been used in the United States, the Far East and Southern Rhodesia, and has been modified to suit Tanganyika conditions.

The chain method of felling leaves the trunks and other debris lying in parallel lines, and it is a relatively simple task in the dry season to bulldoze three of these lines into one. In the trash line thus formed the debris is allowed to dry out and is fired towards the end of the dry season. The unburnt residue is dozed into smaller heaps; and in the second wet season the extraction of roots and whatever stumps have been left is

carried out. The evolution of heavy equipment for this purpose is not yet complete, but it is safe to say that whatever implements are ultimately used will combine horizontal and vertical cutting action. In the subsequent dry season the root debris is collected and added to the felling debris and fired. Land levelling and the construction of soil conservation works then follow, and in the third wet season the land is more or less ready for agriculture.

The foregoing description of the stages of land clearing is a summary of what is emerging as the best practice as a result of four years of intensive experimentation on a large scale. In these years, many and often serious mistakes, which have proved extremely expensive, have been made, but the system set out has proved workable and reasonably efficient. So far the whole of the 140,000 acres provided for by the latest plans has been felled, and the land is ready for agriculture on about 100,000 of them.

The soil conservation system has to take account of the likelihood of downpours of up to three inches in a single hour on slopes not exceeding 5%, since steeper slopes are not cleared. It is based on variable grade terraces discharging into natural drainage lines, which are also left uncleared at the start and are to remain so until experience has indicated to what extent they can safely be cleared or selectively thinned for pastoral work or the production of suitable crops. Where necessary, artificial waterways, the so-called water meadows, are prepared to receive the terrace discharge.

The extraction of economically useful timber, which is not abundant in the areas in which the Scheme is operating, is carried out before clearing begins; much of it is used in construction, usually after pressure impregnation. A part of the less valuable timber is used for fuel and for industrial purposes, such as lime burning.

Agricultural Methods

So far only groundnuts, sorghum, maize and sunflowers have been produced on the large scale, but sunflower production has been abandoned for the present for lack of sufficient natural pollinators and because the varieties available are not adapted to semi-arid tropical conditions.

In the case of groundnuts standard American machinery has been used, but the conditions of production in East Africa are so different from those of the older established groundnut areas in the United States that the equipment has not proved entirely suitable to the work. Also the conditions of very large scale practice require machinery adapted to a very wide range of conditions, whereas on a farm, where at most a few hundred acres are grown, machinery can be suited to the optimum conditions for each operation. In the case of planting the machines must work in a wide range of soil moisture conditions, from very wet to distinctly dry, so that work can proceed with as little interruption as possible. In digging groundnuts, East African conditions are such that the plants come to harvest in a dry, brittle even moribund condition, very different from mature plants as described in, say, North Carolina. In East Africa, while the drying problem is lessened and stooking is often unnecessary, the plants are so fragile that excessive handling may result in heavy loss of nuts, particularly in soils which compact when dry, as many of the red earths do. Windrowing with a side delivery rake is practicable only where harvesting has been carried out at the right time, and attention is now being directed to the development of a combined digger windrower or a combined digger-thresher. Ultimately a digger

combine may well be evolved, from which the nuts will go to drying floors to complete their preparation for storage or shelling. Much work has already gone into the improvement of decorticators, since foreign equipment has proved quite unsatisfactory in East Africa.

In the 1950–1951 season, about 35,000 acres of groundnuts were grown. Maize and sorghum are handled as in American practice, except that under East African conditions it has proved cheaper to harvest maize by hand rather than with a maize picker. The combined area devoted to these crops in 1950–1951 was about 25,000 acres.

The Role of Livestock

The development of cattle farming as an integral part of a mixed agricultural system, or as a parallel venture, has frequently been urged on the Corporation and is always under attention. It is not believed, however, that under the conditions of the three Tanganyika development areas, any benefit would be derived from mixed rotations. In Europe mixed rotations serve the purpose of enriching the crop land with plant foods derived from imported cattle feed. Where cattle feed is not imported, mixed farming merely moves plant foods round the farm; it cannot add to their total amount. Cattle manure produced with added straw or fibrous material, by stall-fed or paddocked animals, would be of great value to ancillary activities, such as vegetable production, but mixed rotations are not necessary for this. The contribution of organic matter by the cattle courses of a mixed rotation would be small and of little significance; for soil improvement in this respect the residues of suitable bulky cash crops or grasses, with appropriate fertiliser nitrogen additions, would seem to offer superior advantages.

The present policy is to develop the production of livestock to a level sufficient to provide animal produce for the European and African staff of the project. This objective alone represents a very considerable undertaking; when it has been attained it will be possible on the experience gained to consider further expansion on a more realistic basis. There is a tendency in all farming, which is particularly prominent in those who observe tropical farming from the vantage point of a temperate country, to exaggerate or even to sentimentalise the role of cattle; in so large and unprecedented a development as the present East African scheme the incorporation of livestock into the farming system can be undertaken only with caution and on the basis of direct local experience. However, it is entirely possible that a considerable parallel development of livestock raising, on land not suited to arable cropping, will take place in the future in the areas controlled by the Corporation.

Research and the Scientific Department

The experience won so far and the mistakes of the past are under constant study by the research and statistical agencies of the Scheme. Costings studies are aimed at the analytical study of actual large scale operations in terms of machine and man hours, fuel costs and general efficiency. This work is supported by experimental costings studies, such as have been recorded by Cameron et al (4).

The Scientific Department, which is the main research agency of the Scheme, has existed since the inception of the scheme in January, 1947, when the writer was appointed to found and direct it. The Department's terms of reference cover research and related activities directed to the establishment of economic systems of mechanised agriculture suited to the varying conditions of the regions with which the Scheme is concerned. The department collaborates in the ini-

tial selection and survey of new areas. Its main task, however, is the execution of programmes of investigation in soil survey and pedology, soil fertility research, agricultural botany (including experimental crop studies, plant selection and breeding), plant protection (including entomology and pathology), meteorology and other related subjects. The Department has developed three experimental stations, one in each of the regions (West, Central and South), each fully mechanised with up to **800** acres of land. At each station the European staff numbers seven, and a large body of African assistants is under training for both field experimentation and laboratory work. The headquarters of the Department, presently at Kongwa, consists of a small administrative section, a library and statistical section, a central chemical laboratory, and a team of senior specialists in the main fields of work outlined above. The Department has had to undertake much important and detailed work with very slender human resources, but this has been possible since emphasis in the earlier stages has necessarily been on the organisation of great numbers of field experiments and on routine laboratory work, most of which could be undertaken by persons without advanced specialist training. Annual reports have been published for the years **1947** through **1950** (**13**, **14**, **15**), and general reviews have also appeared (**1**, **3**).

Soil Research

Soil survey work has been devoted to the field recognition of the main soil types in each region and to field and laboratory work intended to characterise the types pedologically, chemically and physically. From these studies the catenary relationships of the soils and their genesis may be deduced.

Soil fertility studies follow naturally from the pedological work. Their objective is the analysis, by direct field experimentation, of the fertility characteristics of the main soil types and the fertiliser and lime requirements of the main crops on these soil types. Little reliance can be placed on laboratory analysis or pot culture studies in this work at the present stage, since it is evident that only by the results of great numbers of field experiments carried out over a period of years can these more specialised methods of investigation be calibrated. The field experimental methods used throughout the department are those of the Rothamsted school. Results so far show that phosphate deficiency is common in all three regions, and particularly marked in the Southern Province; that the Kongwa soils are well supplied with lime; that small seed bed dressings of nitrogen do not in general increase groundnut yields; that placement of phosphate two inches on either side of the seed is more effective than broadcasting; and that groundnuts, sunflowers and cereals do not benefit from potash additions on any of the soils so far examined. Cereals (maize and sorghum) in the western and southern areas benefit from nitrogenous fertilisers, particularly when these are spread and worked in a few weeks after sowing. Nitrogen fertilisers applied in the seed bed have a generally depressing effect on populations. Quality and yield in Virginia flue cured tobacco at Urambo are determined by the level and balance of nitrogen and potash fertilisers.

Crop Research

The experimental crop studies have three main parts: *a*) introduction and testing of crops and crop varieties, and selection and breeding of improved types; *b*) study of cultural factors, such as optimum population density and population arrangements (spacing and row width), cultivations, ridging, dates of planting and the like; *c*) study of crop sequences and rotations. The ex-

perimental crop studies have resulted so far in the introduction to Tanganyika of at least one crop entirely new to the territory (safflower, *Carthamus tinctorius*), and it is unlikely that dwarf castor bean or Niger oil (*Guizotia abyssinica*) have previously been introduced. The agricultural administrations of most tropical countries have been most helpful in supplying samples of improved varieties of a wide range of crops; and the variety collection now numbers several hundred named varieties of about 40 tropical crops. In the case of groundnuts alone nearly 300 varieties are maintained, and material of species of *Arachis* other than *A. hypogea* has been secured from South America. Selection in groundnuts was first directed to the establishment of a drought-resistant, short season type of good yield for Kongwa. Of the material available, Natal Common has in general proved to be the best variety, but certain Spanish Bunch selections secured from the United States equal Natal Common in performance and have a higher oil content. More recently we have undertaken improvement of long season bunch types, selected from Tanganyika land races found in native production to provide high yielding types more suitable than Natal Common for the two wetter areas, where the harvesting of short season types is usually complicated by continuance of wet conditions. Several of these long season types show a period of seed dormancy after maturity. This characteristic prevents early development of dry season volunteer populations, and so aids in the control of rosette disease (see below). Further, certain of the long season bunch types appear to have some degree of resistance or tolerance to rosette disease. Sunflower work is largely concentrated upon dwarf varieties, including Mauthner's Hungarian, Pole Star, Jupiter, Saturn, Mars and the Canadian selections and hybrids. None of these shows any useful degree of self pollination, and all are very sensitive to drought. Sorghums have been secured from all continents, particularly from the United States. Many types with excellent characteristics have been obtained, and the object of selection and breeding work is to combine these so as to produce a uniform dwarf (or even double dwarf) type with a stout stem and a well exserted shallu-type head. The club-headed types favoured in the United States are not so valuable in East Africa, since the close packing of the grain in the head leads to insect and mould infestations in the warm humid days of the latter part of the growing season. With these characters it is desired to combine the giant yellow grain of the African Kaura or Kifaru types, and the resistance to storage pests conferred by the presence of a horny peripheral layer in the mature grain.

Breeding work in maize has not been undertaken, but instead a wide range of varieties and hybrids has been secured for trial. At Kongwa a semi-dwarf yellow variety from Kenya has proved satisfactory, while in the wetter areas the very mixed Tanganyika selection Katumbili, and a double hybrid from Southern Rhodesia, seem to be the most useful types. East Africa is in need of an extensive hybrid maize development programme, but it is not possible for the Corporation to undertake this work at the present time.

Work on soya bean has demonstrated the unsuitability of almost all American and Southern African soyas for Tanganyika conditions, owing to their lack of adaptation to equatorial day lengths. Six types, all from equatorial or sub-equatorial countries, have, however, proved to be tolerant of short days, making considerable vegetative growth before accepting the flowering stimulus. In a recent trial four of these yielded 1500–1600 lb. grain per acre, against

100–900 lb. for all other types tested. In all crops adaptation to local length of season and a degree of drought resistance are important desiderata.

The work on cultural methods is carried out, naturally, with particular reference to mechanisation problems. Twin-row planting has been examined in groundnuts as a means of giving adequate space to individual plants without reducing the space available for inter-row cultivation, but does not appear to have the advantages expected. Ridging of groundnuts appears to be of importance to minimise the effect of temporary waterlogging, to increase conservation of water and to aid harvesting in soils which tend to compact on drying at the end of the rains. An important aspect of this work is the study by the gypsum block technique of cultural practices in relation to moisture utilisation, particularly in the Kongwa region, where subsoil moisture storage is of the very highest importance.

The rotation studies are concerned in the wetter areas mainly with investigations of the effects of bulky grass or legume crops on subsequent groundnut crops, with special reference to effects on nitrification and leaching of soluble nitrogen, and to improvements in mechanical soil properties. At Kongwa the work turns on the study of bare fallowing in comparison with tumbledown fallow (naturally regenerated grass and weeds). Bare fallowing has already given valuable improvements in groundnut yields in experiments, and moisture studies have shown that it is possible to fill the upland soils with water, to field capacity, in a single season of bare fallow. The tumbledown fallow appears to be extremely wasteful of water.

The general programme of crop research has led of necessity to certain physiological investigations. The growth phenomena of Natal Common groundnuts were investigated at Kongwa in 1950, when it was shown, inter alia, that periods of temporary drought during the vegetative period have little effect on growth rates, and that one third of the final kernel weight (weight of shelled or decorticated nuts) is laid down in the final fortnight of growth, from 91 to 105 days after sowing. This led on the one hand to field studies of the optimum harvesting date, which confirmed the previous finding, and on the other to root bisect investigations. In Natal Common harvesting must take place within a very few days of the optimum time; yield is lost if the plants are dug too early, and nuts are shed if they are dug too late. The bisect work has shown that crop roots at Kongwa penetrate to the maximum depth possible. They usually reach and enter the layer of nodular ironstone which occurs at or near the foot of the profile in the upland soils, at a depth of six to nine feet.

Crop studies have also underlined the importance of the control of surface wash under tropical conditions. Surface wash must be responsible for large and unsuspected losses of topsoil and of crop yield, and none of the standard practices of conservation technique will control it under Tanganyika conditions. Tie ridging (basin listing) gives a very high degree of control if the ridges are very large, but such a method is not convenient with existing machinery. At Urambo a very simply executed broad ridge and furrow ploughing system has been developed by the Scientific Department, giving ridges 12 feet wide, running on or near the contour. Where microslopes are very variable, the open furrows are tied by hand. This method has led to a remarkable degree of control of surface wash, and improves wet conditions and eliminates ponding in seedbeds.

Plant Protection

The plant protection work is based on continuous surveys of the incidence of

disease and insect attack, considered in relation to ecological factors. The clearing of vast acreages in new country may be expected to alter ecological balances in such a way that new pests and diseases may appear, or minor ones become elevated to new importance. We know the identity of all pests and diseases which have so far appeared, and in the more important cases the bionomics have been worked out, and control measures are being studied. The only diseases which have so far assumed major importance in field crops are the well known rosette virus disease of groundnuts, carried by *Aphis craccivora*, *Cercospora* leaf spot of groundnuts, and a leaf spot of safflower (*Alternaria carthami*). Foot rot of groundnuts (*Sclerotium rolfsii*) is increasing in the wetter areas and may well become a major problem in future. Epidemiological studies of rosette have already provided a clear understanding of the field biology of the disease and of its vector, and have led to the successful testing of certain systemic insecticides for the control of rosette. They also indicate a possible means of field control by the provision of dry season alternate hosts for the predators of *A. craccivora*, and suggest the use of seed dormant types of groundnuts as a means of controlling the dry season volunteer growth which can carry the disease over to the next season's crops.

Other fungus diseases, although numerous, are of relatively little importance, with the exception of mildews attacking the maturing heads of sorghum in the wetter areas. The so-called crown rot, a seedling disease of groundnuts caused by *Aspergillus niger*, is largely soil-borne, but it shows no sign of increasing in severity with continued cropping. Entomological problems have been reviewed by Evans (6).

Only one serious new insect pest has so far appeared, *Calidea dregi*, formerly known as a relatively unimportant cotton stainer in East Africa and the Sudan. This insect attacks the developing grains of sorghums and sunflowers, and, in addition to preventing their normal maturation in many cases, it may be present in such vast numbers as to cause major difficulty in the combining of the crop. The insecticides so far tested are not capable of controlling *Calidea* at economic rates of application. Stemborers of various kinds occur with varying severity in sorghum and maize, and the leafhopper *Hilda patruelis*, which causes wilting and death of groundnuts by attacking the underground parts, and is serious in the Singida district of Tanganyika, has been found in two of the regions but has so far caused no loss of crops. Detailed studies have been undertaken on pollination problems in sunflower. Good results have been obtained in the use of benzene hexachloride, applied with the fertilizer at sowing time, for the control of termites' attack on maturing crops.

Broadly speaking, the Department's results show that it is possible to grow a number of crops at a good level of yield in all three Tanganyika areas. The levls of yield produced on experimental plots, however, are only now being approached in practice. Although it may now fairly be claimed that agriculture is well established in all three areas, a major operational research effort is needed to determine and remove the factors which cause practice to lag so far behind research.

The Department collaborates closely with the Tanganyika Department of Agriculture and with the Agricultural and Forestry Research Organisation of the East African High Commission. In this way its results are made available to all concerned with agriculture in East Africa, and it is able to draw on the knowledge and experience of other workers in the same fields. Liaison with

British centres of research and with workers in the British Commonwealth, the United States and French and Belgian colonies is fairly well developed.

The Wider Significance of the Scheme

The importance of the East African development is not confined to the advancement of Tanganyika or the improvement of British food supplies. It has considerable significance for the improvement of world food supplies and for the development of East and Central Africa as a whole. One of the great achievements of the Corporation has been the development of an efficient survey, clearing and engineering development organisation, capable of opening up new country. Such an organisation, with its experienced technical staff, heavy equipment, operators, training wing, maintenance and repair facilities, and supply lines for equipment, spares, fuel, food and accommodation stores, will be a powerful tool for producing agricultural land in the quantities which the world's needs require. The present East African development will be the first prototype product of this tool, and as the first prototype it was bound in its earlier stages to cost more and to be less efficiently produced and planned than could be the case now that the methods and techniques have been perfected. Provided that the resulting production is economic, which at present prices or with improved efficiency could certainly be the case, when transport costs are not too high, there are strong reasons for applying the experience on a wider scale. The problem is essentially similar to that involved in producing, say, a new type of aircraft. For the first prototype a vast amount of research and new equipment and organisation of workshops are needed, which greatly add to its cost. But the building of the first prototype perfects the methods, and later models cost less and are far more easily produced.

The scheme cannot succeed if it is viewed merely as the development of so much new agricultural land. A specific and particularly important human aspect is also involved in the training of great numbers of Africans in new skills and their social readjustment as members of a type of society new to them. The repercussions on tribal society, although indirect, are bound to add to the many pressures which are producing social change in Africa at an ever increasing speed. It is evident that tribalism cannot permanently stand against the advance of modern development in backward countries; all economic advance adds to the power of the attractions which the life of modern society has for primitive peoples. It is indeed the writer's view that these processes are not only inevitable but desirable. It is the task of the more technically advanced peoples to lead the less advanced peoples forward, so that they ultimately come to live as modern men and women, with the corresponding duties and privileges, in the modern world, participating in the common efforts of humanity for the improvement of their lot. This is an entirely different matter from the transformation of backward peoples into economic or social helots, which has been all too common in the past. By the development of training schemes and of systems of promotion based on technical ability and on proved ability to exercise responsibility, and by the provision of advanced types of employment for individuals capable of accepting them, the Scheme is consciously playing a part in this progress and will contribute to the common experience which is being accumulated throughout Africa of how these things are to be done.

No excuse is needed for referring to these problems in a biological presentation of the Overseas Food Corporation's

East African development. The Scheme is part of the beginning of a vast endeavour of our species to expand its food supplies. The human biological questions involved in doing this are as important to the scientist as the more strictly zoological and botanical questions; they are all a part of the ecological appraisal of one of the major tasks of our time.

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Utilization Abstract

Rutin. This drug, medically valuable today in correcting capillary fragility and other hemorrhagic conditions, was first prepared in 1842 from *Ruta graveolens* and subsequently found in a number of plants. It was next produced in some quantity from tobacco, but today buckwheat is the chief American source for commercial production, although much is now being made also from a Chinese drug, wai fa, the flower buds of the Chinese scholartree. "Three species of buckwheat are grown commercially in this country—*esculentum,* or common buckwheat, which includes the Japanese and Silverhull varieties; *emarginatum,* a type resembling Japanese but with a winged seed; and *tataricum*, or Tartary buckwheat, grown primarily for poultry or stock food and sometimes referred to as mountain or bitter buckwheat or duck wheat. For rutin, buckwheat is needed that has a maximum of leaf tissues with a minimum of stem. Most of the rutin is in the leaves and flowers; there is a little in the stems but none in the seeds". Good yields have been obtained in Pennsylvania with Japanese and Tartary varieties, and colchicine treatment of the Tartary has produced a tetraploid which, because of its leafy nature, may be a good source. Some 15 chemical firms now prepare rutin of medicinal grade at an estimated annual output of 15,000 to 20,000 pounds. (J. F. Couch, J. W. Taylor and J. W. White, *U. S. Dept. Agr., Yearbook 1950–1951*).

Breeding Tobacco for Disease Resistance

Resistance toward eight fungal, four virus, two nematode and one parasitic seed-plant disease have almost exclusively occupied the attention of tobacco breeders, and improvement in quality has so far received only negligible consideration.

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The tobacco industry has largely developed around varieties and types of tobacco present on this continent when it was discovered by white men. In spite of the enormous variability in the species *Nicotiana tabacum* L., there has been almost no effort made to develop new types or kinds of tobacco or even to improve the qualities, so far as use is concerned, of those being grown for manufacturing purposes. The greatest change that has been brought about through breeding has been in the development of varieties resistant to disease. These changes have been a matter of necessity if sufficient quantities of tobacco were to be raised to supply the demands. There has been considerable resistance by the trade to the introduction of anything new, particularly in the line of cigar tobaccos, but gradually this resistance is being broken down and some of the manufacturers are becoming eager to assist in the evaluation of new varieties for their own protection against introductions that might change their products. While a great deal of progress has been made in the development of disease-resistant varieties, there is much yet to be done.

Black Root-Rot

Black root-rot is caused by the fungus *Thielaviopsis basicola* (Berk.) Ferraris. It is a destructive disease of tobacco in regions where the temperature following setting averages 70° F. or below (Johnson and Hartman, 1919) and where the soil is not too acid (Anderson et al., 1926; Doran, 1929).

The problem of breeding for resistance to *Thielaviopsis basicola* is complicated by several factors. First, the causal organism is variable, both in culture and under natural conditions (Johnson and Valleau, 1935; Stover, 1950). Allison (1938) recognized four races of *Thielaviopsis basicola* differing pathogenically. When these were tested on four supposedly resistant varieties the results were as follows: Ky 5 was moderately susceptible or susceptible to all races; Special 400 was resistant to one race and moderately susceptible or susceptible to three; Ky 16 was resistant to two races and moderately susceptible and susceptible, respectively, to the other two; while Harrow Velvet was resistant to three races and moderately susceptible to one. The writer had placed the three burley varieties in the same order of resistance on the basis of field trials in heavily infested soil.

Stover (1950) recognized four races occurring in nature: *a*) a brown wild type of high pathogenicity; *b*) a brown wild type of lower pathogenicity; *c*) a grey wild type from areas representing Race 1; *d*) a grey wild type from Virginia, the only area in which brown wild types have not been found.

The greyish olive powdery cultures

described by Johnson and Valleau (1935) evidently correspond to Stover's grey wild types, and their olive and brown cultures from the Station farm evidently correspond to Stover's Race 2. Race 1 came from old tobacco-growing areas, while Race 2 was from areas where tobacco had been grown from a few years up to 20 years.

That races of the fungus can complicate a breeding program is illustrated by the results obtained by Valleau and Kinney (1922). They grew burley selections on a plot that had previously grown only highly susceptible varieties but on which these varieties were a failure from root rot. The resistant selections grew normally while the burley varieties were severely injured. A few years later, in the same plot, the "resistant" selections proved to be highly susceptible, presumably because races capable of attacking them had multiplied.

In 1929 the writer sent seed of selections from several hybrids between resistant and susceptible varieties to the Harrow, Ontario, Station for trial in infested soil. These showed a high degree of resistance in the disease plot at Lexington in 1928, in comparison with a susceptible variety which made no growth. At Harrow the selections "made little growth on the diseased plot and apparently were no better than the nonresistant varieties already in distribution" (MacRae and Haslam, 1935, p. 55).

Somewhat similar results have been obtained with Ky 16 and Ky 41A, two varieties developed by hybridization between one of the selections (W) and resistant varieties. Ky 16 and Ky 41A showed a high degree of resistance for several years when grown year after year on the same plot but eventually were slowed up somewhat in rate of growth so that time of blossoming was delayed a few days. The varieties still show a moderate degree of resistance and are still widely grown as resistant varieties, but the need for a higher degree of resistance is evident, particularly on fields where tobacco is grown year after year. Yellow Special (Mathews and Henderson, 1943) is one of several flue-cured varieties believed to be highly resistant at one time but later recognized as only tolerant (Henderson, 1949).

A second complicating factor is the number of degrees of resistance shown by different varieties in a given infested soil (Johnson, 1930; Mathews and Henderson, 1943). Varieties can be found that show nearly any degree of resistance from those that make practically no growth to those that show no signs of injury under adverse conditions. In the past, varieties of a moderate degree of resistance have sometimes been used as breeding stock in the development of new varieties, only to find that under adverse conditions the new varieties were not nearly so resistant as expected.

A third complication is involved in temperature. If temperatures are relatively high following setting, difficulties may be encountered in the selection of the highest degree of resistance in breeding stock and in hybrid progeny. With lower temperatures, differences become more sharply defined. It is probably in part because of lower temperatures at setting time that root-rot-resistant varieties developed in the North have tended to be more resistant under adverse conditions than some of those developed in the more southern States where temperatures are likely to be higher following setting and "test years" with subnormal temperatures infrequent. If selections were made in the greenhouse during the winter, where the temperature can be kept under 70°, it is likely that strains of a higher degree of resistance could be selected than in the field, particularly in the southern States.

Inheritance of resistance to the black

root-rot organism has been studied but with indefinite results (Johnson, 1921, 1930; McIlvaine and Garber, 1936). It was concluded that susceptibility is recessive and resistance partially dominant and that multiple factors are probably concerned. In Canada it was concluded that resistance is dependent on two pairs of dominant factors and that the degree of resistance appears to be influenced by the number of factors present in the strain (Nelson, 1941; White, 1950). The evidence on which these conclusions were based was not given.

Satisfactory progress has been made in the control of black root-rot through selection and breeding. Resistant varieties have been introduced in Italy (Benincasa, 1916), Pennsylvania (Orton, 1925), Wisconsin (Johnson, 1930), Kentucky (Annual Reports of Kentucky Experiment Station), Virginia (Henderson, 1949), Massachusetts (Kightlinger, 1946), Connecticut (Anderson and Swanback, 1945), Tennessee (Heggestad, 1948), North Carolina (Moss and Bullock, 1942) and Canada (MacRae and Haslam, 1935; White, 1950). Although the resistant varieties have not always been so resistant as desired, they have filled a need for a time until more highly resistant varieties could be developed.

Breeding for black root-rot resistance as well as resistance to other diseases has been rendered easier and more certain by the studies made by the United States Department of Agriculture on over one thousand varieties of tobacco introduced from countries to the south and tested for disease resistance (Clayton, 1947). T.I. 87, 88 and 89 have proved to be highly resistant to black root-rot and have been spoken of as immune. One or another of these has been used in the development of highly root-rot-resistant burley, dark fire-cured and dark air-cured varieties at the Kentucky Experiment Station and perhaps elsewhere (58th Ann. Rep. Ky. Exp. Sta.).

No definite system of breeding has been followed by all breeders in the development of resistant varieties. In breeding cigar tobaccos an effort has been made to produce resistant varieties as nearly identical with accepted varieties as possible, because cigar manufacturers are over-critical of new varieties. In Canada also (White, 1950) the backcross method, with variations, has been employed since 1937. In this method an attempt is made to introduce the desired character into a recognized variety with as little change as possible. In breeding burley tobacco in Kentucky the writer has resorted to hybridization and selection for desirable types in the hope that advantageous plant characters other than the disease resistance factor might be introduced. The same procedure has apparently been followed at the Greeneville, Tennessee, Tobacco Station, where high leaf number has been introduced into burley tobacco as exemplified by the recently introduced root-rot-resistant Burley 1, which is claimed to have about 25 percent more leaves than Ky 16 (Heggestad, 1948). High leaf number tends to improve the quality of the leaves higher on the plant. In Italy black root-rot is a common disease. Varieties known as Burley, Kentucky and Virginia are all highly susceptible, but resistant strains of each have been developed (Benincasa, 1936).

In his pioneer work on burley in Ontario Johnson (1914, 1916) selected 84 resistant plants after inspecting about 5000 acres of diseased tobacco. Some of the selections were " green " in contrast with the white stems of burley, indicating, as Johnson (1930) later concluded, that these were hybrids between burley and some resistant variety of " green " tobacco. From these selections he isolated burley varieties of the drooping type which were of poor quality and did not prove acceptable to the trade (Johnson and Milton, 1919). He then re-

sorted to hybridization between Little Dutch, a resistant cigar tobacco, and Halley's burley. No commercial varieties were reported to have been derived from this cross (Johnson, 1930). Resistant stand-up types were developed from crosses between his Canadian selections and Judy's Pride burley. One of these was grown rather extensively in Canada (MacRae and Haslam, 1935) but was reported to be too fragile a type for general use in the burley area of Kentucky and neighboring States (Johnson, 1930). This variety, in contrast with the earlier Canadian selections, illustrated the desirability of some backcrossing with burley in order to obtain a commercially acceptable type.

Harrow Velvet, a root-rot-resistant burley, was selected at Harrow, Ontario, from seed sent by the writer from Kentucky. The origin of it is obscure. One strain (36–12 according to correspondence) produced a single apparently healthy plant. From the seed of this plant a superior strain was originated. Harrow Velvet is entirely different from 36–12 and evidently resulted from an accidental mixture. It has the appearance and leaf number of the Turkish × burley hybrids which the writer was working with at that time and may have resulted directly from a mixture in 36–12 of a seed of one of the Turkish hybrids. Haronova resulted from a cross between Harrow Velvet and Kentucky Station Stand-up. It possesses high resistance to *Thielaviopsis* and is less susceptible to brown root-rot than Harrow Velvet (Haslam, 1943, 1949). Another burley variety released at Harrow is Harmony. It is highly resistant to *Thielaviopsis*. It resulted from a cross between Harrow Velvet and Halley's Special (Haslam, 1947).

Of the Kentucky burley varieties produced by hybridization, Ky 5 resulted from a cross between a slightly resistant burley selection W, presumably from Judy's Pride, and Dark G, an unknown variety but probably of a cigar type, that was found as a mixture in a row of burley. Ky 5 was moderate in yield but of high quality and only slightly resistant to black root-rot. Ky 16, which has proved to be a very popular variety since 1936 over most of the burley area, resulted from a cross between a Wisconsin burley sent for trial to a Kentucky seedsman (Shipp) in 1930 and Burley 5. Ky 41A, another popular variety with slightly lower nicotine content than Ky 16 and about the same yield and resistance to black root-rot, was the result of a series of crosses as follows: Burley Selection W × Turkish was crossed with Griffin's Goldenback burley, and this crossed with a Wisconsin burley sent in 1930 to a Kentucky farmer by the name of Weathers. An outstanding selection from Mr. Weathers' crop was used. A selection from this series of crosses was crossed with Ky 16, and Ky 41A was selected from the progeny. The series of crosses covered a period of 11 years. These details are mentioned to emphasize the fact that chance plays a great part in the development of a satisfactory variety.

A popular root-rot-resistant flue-cured variety, 400, was discovered when plants were obtained by the Oxford Station from a neighboring farmer. Some plants proved resistant to root-rot and were saved. Another variety, 401, was derived from a cross between 400 and Cash. It is somewhat less resistant to root-rot than 400 but more resistant to leaf diseases than Cash (Moss et al., 1942). Yellow Special, a flue-cured variety with some resistance to black root-rot, was of unknown origin but was found to be resistant in trials (Mathews and Henderson, 1943). Henderson (1942) used Turkish (Xanthia) tobacco as a source of resistance. He found it desirable to use F_3 plants on which to backcross in order to retain resistance. The

flue-cured variety 38 resulted from this line of breeding. Later, Yellow Special, 400 and 402 were found to be only tolerant or partially resistant (Henderson, 1949). Vamor 48 and 50 are two new flue-cured varieties resistant to mosaic and black root-rot developed at the Virginia Experiment Station (Henderson, 1949).

East and Jones (1921) produced a cigar wrapper variety, Round Tip, to order. Resistance to black root-rot was not a specification, but the variety proved to have considerable resistance, probably because only the earliest and most vigorous plants were selected.

In Massachusetts, Havana 211 and Havana K2 were produced by hybridizing satisfactory susceptible types of Havana with resistant types. Havana 211 resulted from a cross of Page's Comstock (res) × Havana 38, while Havana K2 resulted from a cross between Havana Sandman strain × Havana 211 backcrossed with the " regular Havana seed parent ". Both of the new resistant strains are grown commercially (Keitlinger, 1946).

Havana 142 was developed from a cross between Havana 38 (susceptible) with 1207 and 2901 (resistant) selections of Page's Comstock (Johnson, 1930). This variety, known as Resistente 142, is one of the principally grown cigar tobaccos in Italy (Perucci, 1949).

In Connecticut it was discovered accidentally that Connecticut 15 (shade tobacco) is highly resistant. Earlier another resistant shade variety, 4R Cuba, was developed by the Tobacco Station. It is identical with the commonly grown susceptible variety and could be used profitably (Anderson and Swanback, 1945), were it not for prejudices against new varieties of cigar tobacco.

Black Shank

Black shank is caused by a fungus commonly called *Phytophthora parasitica* Dastur var. *nicotianae* Tucker. This implies that it is a separate and distinct strain of *P. parasitica* and that *P. parasitica* is distinct from the similar forms grouped under *P. omnivora*, many of which are known to mate with one another (Leonian, 1931). It is possible that the tobacco pathogen developed in one tobacco area and has gradually spread to the tobacco-growing regions of the world, but there is no evidence that this has occurred. It is more likely that a strain of the fungus capable of attacking tobacco has appeared independently on each continent or island where tobacco is grown and black shank has appeared, and perhaps on several occasions on some continents, as a result of crossing between heterothallic colonies of the fungus, neither of which was capable of attacking tobacco originally. With the appearance of a strain that attacks tobacco, spread by running water, transported soil particles, windborne sporangia, etc. (67th Ann. Rpt. N. C. Exp. Sta., p. 16, 1944) may be rapid.

Control of the disease has not been easy, particularly where the same land is used year after year for tobacco. There is some evidence that the fungus does not live over in the soil (Beets, 1923), but the general consensus is that once established it will remain indefinitely. Although commercial crops can be grown from time to time on infested soil without appreciable loss, this means of control cannot be resorted to except where good tobacco land is abundant. It has proved necessary, therefore, wherever the fungus has become established, to develop resistant varieties.

D'Angremond (1919) realized this possibility and commenced work in the Dutch East Indies on selection and hybridization. He was able to demonstrate resistance in certain varieties. This work was continued at least through 1937 with the development of some re-

sistant strains of satisfactory quality. These proved to have some resistance to powdery mildew also, but were susceptible to the slime disease (Coolhaas, Thung and Middlebury, 1938). The Timor variety was found resistant to black shank (Thung, 1938).

Following the appearance of black shank in Florida cigar wrapper tobacco about 1915, the fungus spread rapidly through Gadsden County and eventually reduced the acreage greatly. In 1922 Tisdale (1922) began a study of the disease, and in 1926, in an extensive report (Tisdale and Kelley, 1926), showed that the types of tobacco grown in the United States are all highly susceptible to the disease; but 17 percent of a strain of Big Cuba, two percent of Connecticut Broadleaf, six percent of Maryland Mammoth, and seven percent of a Porto Rican variety survived. Seventy percent of *Nicotiana rustica* survived, but attempts to cross it with cigar tobacco proved futile. From this unpromising beginning in 1922 one strain of Big Cuba survived 88 percent in 1923, though most of the selections were much more susceptible. By constant selection and self-pollination, strains were isolated by 1928 in which about 90 percent of the plants were living at the end of the season and in which the quality was as good as Big Cuba. In 1923, selections were also made for resistance in Little Cuba. The following year 50 percent of the plants were healthy at the end of the season and another 30 percent were alive. In three more years a high degree of resistance was established. Resistance was also established in the varieties Santiago (Java) and Dubek (Russia). These results indicate that the varieties from which the selections were made had been mass selected and that considerable cross pollination had taken place. When self-pollination and selection were resorted to, the resistance genes were concentrated and lines were soon established showing a high degree of resistance.

As the selected lines were not entirely satisfactory from the standpoint of the trade, crossing was resorted to in order to develop satisfactory varieties (Tisdale, 1931). The F_1 crosses were tested in infested soil, and nearly all of the plants of a cross between resistant Big Cuba and Round Tip died. The F_2 of the survivors showed between seven and ten percent resistance; the F_3, 25 to 41 percent; the F_4, 0 to 83 percent; the F_5, 33 to 100 percent; and the F_6, 89 to 100 percent. This was the origin of No. 1. Strains R and Rg were developed from what was probably a natural cross between Round Tip and Big Cuba. Highly resistant strains were derived from this cross in four years.

Partially resistant strains of Big Cuba (48 percent healthy) crossed with Little Cuba (50 percent healthy) gave an F_2 population ranging from 22 to 61 percent resistant, but a high degree (90 percent) of resistance was established in four years. From this cross 301 was developed. During the process of development of these resistant varieties, attention was given to selection for the best agronomic types, the poorer strains being discarded. Using the same technics, other varieties were developed. Rg, one of the best of the resistant varieties, was subjected to several years of selection for both quality and resistance until, in 1947, 100 percent of Rg plants were alive at the end of the season and 100 percent of a susceptible variety were dead (Kincaid, 1947).

In Puerto Rico, Nolla (1929*a* and *b*) studied the local varieties of cigar tobaccos for resistance and also F_1 crosses of these, with interesting results. A Puerto Rican cigar wrapper type improved from local stock was almost immune. The " Pais " cigar filler type was highly resistant, as were some other

wrapper and filler types. Round Tip or Borinquen as well as some local types were highly susceptible. When three resistant varieties were crossed, respectively, with three susceptible varieties and the F_1 grown in infested soil, results were obtained that were in marked contrast to those obtained by Tisdale. In the F_1 generation an average of only 44 percent of the plants became diseased, in contrast with nearly 100 percent in the Florida F_1 progeny. The F_1 of Consolation, a highly resistant variety, × Experiment Station, and its reciprocal, had only 19.1 and 15.3 percent diseased plants. Vuelta Abajo, a slightly less resistant variety, crossed with Experiment Station, and the reciprocal, had 50.9 and 70.33 percent diseased; while Vuelta Abajo × Round Tip (Bor.), and its reciprocal, had 42.61 and 24.72 percent diseased. The slightly less resistant Ceniza × Experiment Station, and its reciprocal, had 55.49 and 78.89 percent diseased plants, respectively, in the F_1. Under the same conditions the F_1 susceptible × susceptible all died, while the highly resistant strains were on an average over 95 percent healthy.

It would seem from these results that there are distinct differences in the degree of resistance in the resistant varieties which appear not only when the varieties themselves are compared directly but also in the F_1 when the resistant varieties are crossed with susceptible varieties. It would be a great help to the breeder if 80 percent of the F_1 progeny lived, as in the cross Consolation × Experiment Station, rather than about one percent as in some of the Tisdale crosses. It is probable that with the higher resistance much more rapid progress could be made in the development of resistant varieties of now highly susceptible types. Studies on black shank were continued in Puerto Rico. In 1945 it was reported that eight varieties showed resistance, with Florida Rg showing the highest degree (Ann. Rep. Tob. Inst. Puerto Rico 1941–42, 1942–43, 1945).

Black shank eventually developed in the flue-cured area of North Carolina and it became necessary to develop resistant varieties. Using Florida 301, Bullock (1943) developed four varieties of flue-cured tobacco of satisfactory resistance and fair quality. Oxford 1, 2, 3 and 4 were developed by crossing 301 with Virginia Broadleaf, Virginia Broadleaf, White Stem Orinoco and Warne, respectively. The flue-cured varieties were backcrossed on the resistant selections twice before the final selections were made. These varieties were recommended for use only in infested land.

A decided advance was made in North Carolina with the introduction of the Dixie Bright varieties 101 and 102. These two varieties are resistant not only to black shank but to Granville wilt also. They were derived from T.I. 448 (Granville wilt res.), Florida 301, Virginia Brightleaf and 400 (Cummings, 1950).

Jenkins (1949) developed 12 flue-cured resistant varieties in Virginia, the Vesta series. He has also introduced the resistance factor into burley tobacco. Some work has been under way to develop black-shank-resistant varieties of dark fired tobacco in Tennessee (56th Ann. Rep. Tenn. Agr. Exp. Sta.).

Some other species of *Nicotiana* have been shown to be highly resistant to black shank. *N. repanda, N. rustica* and *N. longiflora* show definite resistance. Infection on *N. repanda* was limited to the succulent stems and leaves but was frequently corked off at the crown. The F_1 of $4n$ *N. repanda* × $2n$ *tabacum* grew slowly but died following transplanting (Foster, 1943). Kincaid (1949) found *N. repanda* and *N. plumbaginifolia* moderately resistant to black shank, and

made hybrids between these species and *N. tabacum* for the purpose of developing highly resistant tobacco varieties.

Blue Mold or Downy Mildew

Blue mold of tobacco is caused by the fungus *Peronospora tabacina* Adam. The disease is destructive in Australia and in North and South America, principally in plant beds, but sometimes it appears during cool wet periods in the field. The fungus is present on wild species of *Nicotiana* in North and South America and in Australia (Wolf, 1947). It was twice introduced into the tobacco-growing area of the United States, in 1921 and in 1931. In 1921 it affected cigar tobacco in the Florida-Georgia area but failed to survive. In 1931 it became established in the newly developed flue-cured area of southern Georgia, where it persisted, probably on volunteer tobacco and as oospores in old beds.

The disease can be controlled by proper spraying or dusting, but only a relatively small proportion of growers resort to this means of control because in an average year they are successful in raising sufficient plants in spite of the disease. For this reason losses are enormous in epiphytotic seasons. Even a moderate degree of resistance, which would slow up spore production and delay northward spread, might conceivably eliminate severe epiphytotics and greatly reduce carry-over from season to season.

Over 1000 varieties of tobacco, mostly from Mexico, Central and South America, have been tested for resistance to blue mold (Clayton and Foster, 1940; Clayton, 1945). A few varieties, mostly from Argentina, were slightly resistant. Under conditions of moderate attack in the plant bed, T.I. 57 (Chileno Correntino) frequently showed striking evidence of resistance; however, when conditions were optimum for the disease, resistance broke down almost completely. In crosses with Gold Dollar and White Stem Oronoco, selections in F_2 never fully recovered the resistance of T.I. 57, and it was concluded that there was little prospect of obtaining satisfactory resistance to blue mold in *N. tabacum* by intraspecific hybridization (Clayton, 1945). However, it would have been interesting to see to what extent a variety such as T.I. 57 would have been affected year after year and to what extent oospore formation would have occurred. In most years attacks of the fungus in Georgia are only moderate, and under these conditions T.I. 57 shows " striking evidence of resistance " (Clayton, 1945). Resistance of this degree would delay production of conidia and delay the northward advance of the fungus and perhaps greatly reduce carry-over in most years. If interspecific crosses are not successful, it may be well worthwhile to go back to varieties such as T.I. 57 as a source of resistance. Kincaid (1939) started work on the development of resistant tobacco, using Chileno Correntino as the source of resistance.

Sixteen wild introduced species were studied in Australia and all found to be susceptible, although some exhibited a considerable degree of resistance (Angell and Hill, 1932). A further study, including 250 varieties of *N. tabacum*, 21 varieties of *N. rustica* and introduced species of *Nicotiana*, showed that none of the *N. tabacum* varieties had seedling resistance, although there were slight differences. No introduced species was resistant, but the five Australian species showed high resistance or immunity. Of these, *N. debneyi* was thought to have some promise as a source of immunity if crossed with *N. tabacum* (Smith-White et al., 1936).

Clayton (1945) studied 33 species of *Nicotiana* for resistance in plant beds, in several locations, and in transplanted seedlings in pots in the greenhouse dur-

ing the winter months. He found that very young seedlings of a species might be susceptible, but as they aged they became more resistant. *Nicotiana debneyi* Domin., *N. exigua* H.-M. Wheeler, *N. Goodspeedii* H.-M. Wheeler, *N. longiflora* Cav., *N. maritima* H.-M. Wheeler, *N. megalosiphon* Heurck and Muell.-Arg., *N. plumbaginifolia* Vir. and *N. rotundifolia* Lindl. were found to be immune to highly resistant. Of these, all are Australian species except *longiflora* and *plumbaginifolia*, which are from Argentina. *N. acuminata* (Grah.) Hook, *N. caesia* Suksd., *N. gosseii* Domin., *N. paniculata* L. and *N. rustica* L. were moderately resistant (Clayton, 1945). Successful crosses were made between *N. tabacum* and *N. debneyi*, *N. megalosiphon*, *N. longiflora* and *N. plumbaginifolia* by Clayton. The most promising results appear to have resulted from crossing *N. tabacum* with a tetraploid *N. debneyi*, as this produced a fertile hybrid. After the fourth backcross, *tabacum*-like plants of the flue-cured type were selected that appeared to have 24 pairs of *tabacum* chromosomes plus the resistance from *N. debneyi*. Homozygous resistant plants had not appeared by 1949 (Clayton, 1949), but Clayton has since informed the writer that he has homozygous strains.

Hybrids of *N. debneyi* × *N. tabacum* backcrossed with *N. tabacum* several generations proved to be completely male sterile so long as *N. tabacum* was never used as the female parent (Clayton, 1950). Sterility is evidently induced by *N. debneyi* cytoplasm.

Kincaid (1949) made hybrids between *N. tabacum* var. Rg and *N. debneyi*, *N. repanda* and *N. plumbaginifolia* for their possible resistance to downy mildew, black shank and root knot. The T × D hybrid showed no resistance to blue mold in the plant bed, but in the field seemed to possess some resistance, possibly associated with the quick drying characteristic which the hybrid has in common with *N. debneyi*. The quick drying character in the variety Chileno Correntino appeared to be due to a single dominant factor (Kincaid, 1949).

Fusarium Wilt

Fusarium wilt is caused by the fungus *Fusarium oxysporum* var. *nicotianae* J. Johnson. It was first recognized in this country in Maryland in 1916, and in burley tobacco in Ohio in 1919 (J. Johnson, 1921). It was not until about ten years later that an occasional specimen of the disease was received at the Kentucky Experiment Station. By 1940 the disease was fairly common in sandy soils along the Ohio River and along creek bottoms, and sometimes on higher ground in other parts of the State. At the present time it can be found nearly anywhere in the State but is still comparatively rare in the Central Bluegrass area in the vicinity of Lexington. It apparently is not a factor in the cigar tobaccos, as they seem to be highly resistant. It is not likely to be a problem in the newly developing Turkish or Aromatic tobacco area in the Carolinas and Virginia, as the Turkish varieties seem to be almost immune (Armstrong, 1947). In the flue-cured areas wilt occurs only in rotations with sweet potatoes (Clayton, 1944), and is more prevalent in southeastern North Carolina (Clayton, correspondence). Only a few farmers have trouble with fusarium wilt in South Carolina (Armstrong, 1947). Shaw (1939) reported the first case of wilt at the McCullers Tobacco Station in North Carolina in 1939, on Gold Dollar following sweet potatoes that had been inoculated with the wilt organism.

The fusarium wilt organism (*F. oxysporum* var. *nicotianae*) is not a single variety, as the name would indicate, but is made up of strains of *F. oxysporum* that cause wilt in tobacco, sweet potatoes and cotton. Armstrong (1939) ob-

served that when burley tobacco was grown in the Piedmont section of South Carolina for the first time, on land that had previously grown cotton, it was injured by wilt. This led to a study of the relation between various wilt diseases of cultivated crops. Wilt of tobacco may be caused by each of at least three strains of the fungus. Strain 1 attacks burley tobacco and sweet potato but not flue-cured tobacco or cotton; 2 attacks burley, flue-cured tobacco and sweet potato but not cotton; 3 attacks burley tobacco and cotton but not flue-cured tobacco and sweet potatoes. Thus there are two strains known to attack sweet potato (1 and 2), one attacks cotton (3), two attack flue-cured and dark tobaccos (2 and 3), and three attack burley tobacco (1, 2, and 3) (Armstrong, 1940; Armstrong et al., 1942; Smith and Shaw, 1943). Thus flue-cured and dark tobaccos may be grown safely after cotton but not after sweet potatoes, while burley and Maryland tobaccos may be affected after either sweet potatoes or cotton. It is obvious that wild-resistant varieties to be satisfactory should be resistant to all three strains of the fungus. Armstrong and Armstrong (1948) have extended this work to show that many species, apparently immune to fusarium wilt, may have hyphae of *F. oxysporum* in their vascular systems.

Because it is caused by a soil-borne fungus that persists in the soil, the logical method of control, as for other *Fusarium*-induced wilts, is through breeding for resistance.

Johnson (1921) studied the resistance of 12 varieties and a hybrid to the organism and found cigar tobaccos, Narrow Leaf Oronoco and Blue Pryor, were resistant, while Maryland Broadleaf and burley were susceptible. A black root-rot-resistant burley had some resistance, and an F_1 hybrid of it with susceptible burley showed some resistance.

When it became evident that the disease might become common in Kentucky (1932), work was started on the development of resistant varieties at the Kentucky Agricultural Experiment Station. It was soon evident that there was little chance of getting resistance from the old established burley varieties, as they appeared to be highly susceptible. However, some of the burleys of hybrid origin developed for resistance to black root-rot showed some resistance. A petiolate Turkish variety was practically immune, as were Baur's low nicotine, Havana and Cuba tobaccos, and Pennsylvania Havana 18. The dark fired and air-cured varieties of western Kentucky presented an interesting condition. Up to the present the disease is of no importance in these varieties but causes considerable damage to burley and one sucker tobaccos in some parts of the dark air- and fire-cured areas of the State. In tests of dark-fired varieties the plants could be divided into three groups—healthy, affected but living, and dead. Of 141 inoculated plants of eight varieties, 65 percent developed signs of wilt but lived; 27 percent remained healthy; while only eight percent died. This degree of resistance seems sufficient to protect plants from wilt under ordinary field conditions. Highly susceptible varieties when inoculated and set in the field usually die in three to four weeks following setting, without making any growth.[1]

In 1933 a statement was published (Ky. Agr. Exp. Sta., Ann. Rep. 1933) to the effect that resistance to wilt appears to be a recessive. This was based

[1] The method of testing for resistance in the field used at the Kentucky Experiment Station is to inoculate flasks of sterile moist wheat with the organism a few days before transplanting, and at the time of transplanting to dip the roots in a water decoction of this material. Agar cultures in Petri dishes inoculated a few days before transplanting work equally well and are now used. Several separate isolations of the fungus are always mixed.

on an F_2 population of 1025 plants of hybrids between highly susceptible burley and highly resistant Turkish. Two hundred and seventy-five, or 26.8 percent, remained healthy, while 753 developed wilt or died; of these 176 lived at least beyond the time when highly susceptible plants were dead. In going over the records again and in the light of further experience it is difficult to say whether resistance is recessive or is sometimes dominant. Resistant or moderately resistant varieties may have a fairly high proportion of plants that develop the disease but are resistant enough to struggle through the summer and sometimes even recover and grow normally. In 1934 the F_1 of the Turkish crosses just mentioned was tested. One hundred and twenty-one plants of Judy and Kelly × Turkish were grown. Fifty-nine developed symptoms of wilt but were not killed, and 62 remained healthy. The fact that the F_1 plants were either healthy or, if infected, were alive and growing when plants of susceptible varieties were dead or dying indicates that resistance in Turkish tobacco is at least partially dominant. If it were recessive the F_1 would have died just as the susceptible parent did. That there was no clear-cut Mendelian segregation, except in the plants that remained healthy in the F_2, might be explained on the basis that other genes play a part in the reaction of a plant toward the fungus—that is, when enough Turkish genes are present with the resistant gene, as in the F_1, all plants may show a fairly high resistance, but when these influencing genes are more diluted, as would occur in the F_2, the degree of apparent dominance of the resistant gene could be markedly influenced, and many plants carrying but a single gene might succumb. Thus it is possible that the resistant gene of Turkish might act as a partial dominant or even a recessive, depending on the remaining genetic makeup of the plant. Occasionally Turkish tobacco will show slight symptoms of wilt in homozygous resistant plants.

In contrast with Turkish hybrids was the F_2 Cuban × Ky 5 (sus.); 26 plants showed symptoms of wilt, 52 were healthy (29.4 percent), and 99 were dead at a time when practically all plants of susceptible varieties were dead. The 29.4 percent healthy plants is not far from an expected 25 percent if resistance is controlled by a single factor pair. The F_1 of this cross was grown the following year, and all plants were dead four weeks after setting. In this instance resistance was recessive in the F_1 but not completely so in the F_2.

In 1950, McCuller's 27 (70th Ann. Rep. N. C. Agr. Exp. Sta., 1947), sent to the writer as very highly resistant to wilt, had one plant of 34 with mild wilt symptoms. The F_1 of McC. 27 × Ky 57 (sus.) had 17 plants with mild wilt symptoms in a total of 60. The affected plants survived the summer. In this instance resistance is partially dominant, as in Turkish, but the degree of resistance has been affected to some extent as compared with the resistant parent, as evidenced by the higher number of plants with mild wilt symptoms. Green River M14, Harrow, had one of 29 plants with mild symptoms of wilt. The F_1 was not tested, but the F_2 of M14 × One Sucker (susceptible) had 14 healthy, 34 with wilt, and 12 dead in a row of 60 plants on July 9, over five weeks after setting. This might be interpreted as 14 homozygous resistant, 34 heterozygous and showing signs of wilt but not killed, and 12 homozygous susceptible—not too far from a 1 : 2 : 1 ratio in a small population.

From these meager records it may tentatively be concluded that resistance to fusarium wilt is controlled by a single factor pair that is partially dominant or recessive.

In Maryland, where wilt is a factor

in tobacco production, 65 varieties and strains have been tested in infested soil. Of these, 14 were resistant and 51 susceptible (51st and 52nd Ann. Rep. Md. Agr. Exp. Sta.). Catterton Broadleaf was tested at the Kentucky Experiment Station in 1950 and found to be resistant, although five of 31 plants developed mild symptoms. Robinson Medium Broadleaf is the most widely used resistant strain in Maryland (Clayton, correspondence). Although wilt is not a factor except following infected sweet potato in the flue-cured area, work is being carried on to develop flue-cured varieties resistant to the sweet potato fungus. Highly resistant Tobacco Introduction lines T.I. 566 and T.I. 55C were crossed with Gold Dollar and 401, and promising lines selected from the progeny. McCuller's 27 resulted from a cross of T.I. 566 × G.D. × 401. However, Oxford 26 and several of the Granville wilt-black shank resistant lines are showing a high or fair degree of resistance to wilt (Todd, 1948).

In the burley area it has been necessary to resort to breeding for resistance, as the old burley varieties show no resistance. Several varieties, including Ky 31, 32, 33, 34 and 35, have been introduced from time to time by the Kentucky Agricultural Experiment Station. None of these varieties has been found entirely satisfactory, for various reasons, although Ky 35 is now being grown extensively, even on farms where wilt is not a factor.

The origin of these varieties is as follows: Ky 31 resulted from a cross of Ky 7 × Ky 12. Ky 7 had some resistance which could have been derived only from Turkish. Ky 12 showed some resistance, probably derived from Routt's resistant, a burley colored tobacco selected in Canada for resistance to black root-rot. Ky 31 was not of satisfactory quality, although satisfactory from the standpoint of fusarium resistance.

Ky 32 resulted from the same cross that produced Ky 16—that is, Wisconsin (Shipp) × Ky 5. Resistance undoubtedly came from the Wisconsin burley, apparently one of those selected in Ontario for resistance to black root-rot and apparently originating from a cross between burley and some dark green variety.

Ky 33 was derived from a cross of Ky 7 × Turkish crossed with F_2 Ky 12 × Ky 7, and this combination was crossed with Ky 32. Ky 33 proved to be highly resistant to fusarium wilt, although in a hot season inoculated plants might develop symptoms. It was extensively grown in wilt areas until the introduction of Ky 35 and proved entirely satisfactory so far as wilt resistance was concerned. It was an erect variety, growing rapidly but producing low yields in hot dry seasons, and very heavy yields of high quality tobacco in favorable seasons. It blew over too readily in wet windy weather.

Ky 34 was derived from a burley variety received from the Greeneville, Tennessee, Tobacco Station and presumably developed from a cross between Chileno Correntino and Judy. It had some resistance to black root-rot and was found to have moderate resistance to fusarium wilt. Mosaic resistance (glutinosa) was added to this variety and it was designated Ky 34. It yielded heavily and the quality was good, but the leaves were large and close together and the tobacco proved hard to cure; it also blew over in wet windy weather. It was not grown extensively, although a few farmers still grow it successfully.

Ky 35 was derived from a cross between Ky 34 and a mosaic-resistant burley derived from the sixth backcross generation of Ky 16 on *N. digluta*. Ky 35 is high yielding, usually of good quality, is moderately resistant to black root-rot and wilt, and resistant to mosaic. It stands up well in wet weather. Its greatest objection is that it develops a

necrotic leaf disease when infected with the veinbanding virus from potato. It is also more sensitive to corn pollen than other varieties, sometimes developing severe leaf spotting when grown near a field of corn. Wilt-resistant varieties have now been developed that are more resistant to black root-rot than Ky 35, that are mosaic-resistant, and that appear to develop only the mild disease common to other burley varieties when inoculated with veinbanding virus. Ky 35 derived its sensitivity to the veinbanding virus from Ky 34, and it probably derived it from Chileno Correntino. Considering the increasing prevalence of fusarium wilt in the burley district, it will probably be necessary eventually to introduce a high degree of resistance to wilt into all new burley varieties.

Powdery Mildew or White Mold

Powdery mildew of tobacco is caused by the fungus *Erysiphe cichoracearum* DC. It occurs in Africa, Europe, Asia and the Dutch East Indies and has been reported as occurring on tobacco in Brazil (Averna-Sacca, 1922), Guatemala (Palm, 1932), Mauritius (1925) and Madagascar (1925). In Madagascar it is reported to be more severe in the highlands than in the lowlands (Bouriquet, 1934). The strain of the fungus that attacks tobacco is evidently one found on native vegetation and on cucurbits (Deckenbach, 1924).

In Crimea, in a district where a variety known as American is grown, there was less mildew, and this was attributed to the inherent resistance of this variety (Alexandroff, 1927). In southern Rhodesia the use of the heavier types of tobacco, such as Orinoco White Stem and Warne, seemed to reduce the amount of the disease (Hopkins, 1931), while in Nyasaland powdery mildew appeared to be gaining ground with the extended cultivation of the moderately susceptible Hickory Pryor variety (Butler, 1928; Hopkins, 1928). In the Dutch East Indies the Timor-Vorstenland variety remained practically immune from infection, whereas the adjacent rows of Chlorina and KW 10 were heavily infected (Thung, 1939). D'Angremond (1928) and Thung (1935) observed that the broad-leafed varieties, such as E3K and EK, were more severely affected than those of less luxuriant growth, as Kanari and Y10. In Italy tobacco varieties were studied for resistance, but no fully resistant varieties of *N. tabacum* could be found, and the conclusion was drawn that it would be necessary to resort to breeding for partial resistance or resort to interspecific crossing (Scaramuzzi, 1948).

Ternovsky (1934) studied 18 varieties of *N. tabacum*, seven of *N. rustica*, 18 wild or decorative species and eight species crosses for their resistance to mildew. All of the tobacco varieties were susceptible in the greenhouse, but in the field there were distinct differences in the intensity of the disease. Three of the *N. rustica* varieties remained free from mildew, while the others had a less intense disease than tobacco. All of the 18 wild or ornamental species tested were immune except that *N. glauca* and *N. sylvestris* contracted an insignificant degree of infection, the former in the field and the latter only in the greenhouse. He pointed out (1935) that the chief interest in the *tabacum* × *glutinosa* cross was in its complete immunity to *Oidium* derived from *glutinosa*. The F_1 *N. tabacum* × *N. sylvestris* and *N. tabacum* × *N. glauca* were less severely affected than the *N. tabacum* parent; while *N. glutinosa* × *N. tabacum*, *N. tabacum* × *N. sanderae*, and *N. rustica* × *N. tabacum* remained immune. *Nicotiana glutinosa, paniculata, Langsdorffii, alata, Sanderae, noctiflora, plumbaginifolia, longiflora, acuminata, repanda, nudicaulis, australis, fragrans, commutata, Bigelovii* and *Suaveolens* demonstrated

complete immunity both in the greenhouse and in the field.

Using *N. digluta* as a source of mosaic and powdery mildew resistance, Ternovsky (1941) developed a considerable number of strains of tobacco resistant to both diseases and equal in yield and quality to Dubec 44 which was used as the backcross parent. Satisfactory quality was not attained until the fourth or fifth backcross. There is good reason to believe, from the results, that varieties of any type resistant to both mosaic and powdery mildew could be developed by backcrossing on *N. digluta.*

Bacterial Wilt

Bacterial Granville Wilt, or slime disease, of tobacco is caused by *Bacterium solanacearum* E.F.S. The disease was present perhaps 25 years before it was reported as being present in Granville County, North Carolina (Stevens and Sackett, 1903). While it was then restricted to a limited area, it has gradually developed in neighboring counties and become a very destructive disease. It is also present in the Dutch East Indies, Japan and China. The organism attacks species in many other genera.

In 1904 Stevens outlined possible methods of control, emphasizing resistance as the most logical (Stevens, 1906). Of 62 American varieties tested on sick soil, a few had some degree of resistance as compared with the most susceptible. One of these varieties lost only 40 plants of 900, while susceptible varieties were severely injured (Stevens, 1908). The resistant varieties were apparently varieties that show considerable resistance one season but none the next (Garner, Wolf and Moss, 1917); at least nothing came from this approach and the breeding work was discontinued for a time (Clayton and Smith, 1942).

In Sumatra, Honing (1910) tested tobacco varieties from various parts of the world but found none more resistant than the local Sumatra. Other species of *Nicotiana,* 29 in all, have been grown in infested soil, but all proved to be susceptible (Garner et al., 1917; Kuijper, 1928; Clayton and Foster, 1940; Clayton and Smith, 1942). These species included both *N. sylvestris* and *N. tomentosa* but not *N. tomentosiformis.* It was from these species that *N. tabacum* was supposed to have originated (Goodspeed and Clausen, 1928).

Work was again begun on breeding for resistance in North Carolina in 1934 with a study of 1034 collections of tobacco from Mexico, Central and South America. These were screened in the greenhouse by inoculating ten plants of each collection with *Bact. solanacearum.* In a mixture of three varieties from Colombia, a single plant (T.I. 448A) was found that proved to be highly resistant to wilt and mosaic.

In addition to the high resistance to wilt found in the progeny of this plant, disease index (D I) 7.5, other varieties with intermediate resistance were found, as T.I. 79A (D I 35.6), Xanthi (D I 23.8) and 79–X a hybrid of T.I. 79A × Xanthi (D I 20). Some other varieties with a slight degree of resistance were also recognized in the study, such as Davis Special, with a high disease index on heavily infested soil but an index of only about 60 on less heavily infested soil (Smith and Clayton, 1948).

Fortunately T.I. 448A was similar in plant type to flue-cured tobaccos and produced a cured leaf of fair color and no undesirable aroma. It was crossed with several varieties of flue-cured tobacco and selections made for resistance, type and the cured product. From a cross of T.I. 448A and 400, Oxford 26 was derived in the fifth generation and introduced to growers. It has proved highly resistant to wilt, although as many as 20 percent of the plants may show temporary signs of wilt early in the season and a few may die (Smith,

Clayton and Moss, 1945). Usually in heavily infested soil from 95 to 100 percent survive. While Oxford 26 appeared to be satisfactory in both yield and quality when released, it was later reported as not entirely satisfactory, and a new line (8238, Dixie Bright 27) was introduced to replace it (Moore, Lucas, Clayton, 1949). T.I. 448A carried as recessive factors two root troubles, one of which was parasitic, and a leaf-spot disease which increased the difficulties of obtaining satisfactory wilt-resistant varieties (Smith, 1947).

Black shank has recently entered the wilt area of North Carolina, causing confusion among growers as to which disease was causing their losses. This made it desirable to develop varieties resistant to both diseases. In 1949 Dixie Bright 101 and 102 were released by the North Carolina Experiment Station. These varieties are as resistant to black shank as Oxford 1 and as resistant to wilt as Oxford 26. They derive resistance to wilt from T.I. 448A, their black shank resistance from Florida 301; and Virginia Bright Leaf and 400 were the flue-cured parents of each. Dixie Bright Leaf 101 is higher yielding than 102, but 102 has higher quality than 101.

Although a satisfactory degree of wilt resistance was not known until it was found in T.I. 448A, there was an appreciable degree of wilt resistance in some tobacco varieties (Stevens, 1908; Garner, Wolf and Moss, 1917). Also, a limited resistance was found in introduced varieties (Clayton and Smith, 1942) and in the flue-cured varieties Davis Special, Pinkney Arthur and 400 (Smith and Clayton, 1948). Efforts to increase this type of resistance by line selection failed, but from the cross Davis Special × Pinkney Arthur a strain with a grade index of 55.8 was obtained. The parents had indices of 74.7 and 82.0, respectively, while a susceptible variety might have an index of 98.6, and T.I. 448A an index of 10. The F_1 of D.S. × P.A. was completely susceptible, suggesting that the resistance factors are different in the two varieties and that both are recessive. Similarly the F_1 of a cross of two highly resistant strains of T.I. 448A × 79–X (disease indices of about 10) had a significantly higher disease index than the parents, but continued selection through the sixth generation did not increase the resistance above that of T.I. 448A. When T.I. 448A was crossed with susceptible varieties of flue-cured tobacco the F_1 was almost as susceptible as the flue-cured parent. Here again resistance was recessive. No F_2 lines showed a high degree of resistance, but F_3 lines were found that were highly resistant. In F_7 the resistance showed no increase over that of T.I. 448A. Resistant F_3 selections gave approximately the same results in subsequent generations, when backcrossed with the susceptible parent, as were obtained from the original cross, indicating that all the resistance genes were associated in F_3.

The two slightly resistant varieties 400 and Davis Special, when crossed with T.I. 448A, had significantly fewer diseased plants in the F_2 than crosses in which more highly susceptible varieties were used. This aided greatly in the selection and development of resistant varieties. Smith and Clayton (1948) concluded that wilt resistance is recessive and controlled by multiple genes.

In the Dutch East Indies resistance to slime disease has been tested by dipping seedlings in a bacterial suspension and setting. This kills all susceptible plants, but Sumatra R-line hybrids survived 60 percent (Van Schreven, 1948).

Wildfire and Angular Leaf Spot

Wildfire and angular leaf spot of tobacco are diseases caused by *Pseudomonas tabaci* (Wolf and Foster) Stapp, and *P. angulata* (Fromme and Murray) Stapp, respectively. These so-called

species are probably strains of a single species, the strain causing wildfire having the property of producing a chlorolytic exotoxin that causes a yellow halo around the points of inoculation. There is conclusive evidence that the wildfire organism may change to what appears to be the angular leaf spot organism under conditions not well understood (Braun, **37**), and evidence that the angular leaf spot organism may change to the wildfire organism (Valleau et al., **1943**). While there is no absolute experimental proof of changes in this direction, observations in Kentucky indicate that it occurs. For many years wildfire was so rare in Kentucky that recommendations for control were not deemed necessary (Valleau and Johnson, **1932**). However, angular leaf spot was nearly always present in beds and fields. In **1950**, in contrast, wildfire occurred in nearly all untreated plant beds, while angular leaf spot was rarely found. Evidently a mass change had taken place in the ability of the organism to produce toxin. The normal life of the organism is spent amongst the root hairs of several pasture and crop plants and weeds, and is entirely independent of tobacco (Valleau et al., **1944**). When infection occurs through the stomata of tobacco leaves or other susceptible hosts the organism evidently finds conditions on the surface of the leaf parenchyma cells similar to those among the root hairs, and multiplication occurs with the resulting disease. Thus the relation between the host and the pathogen is purely accidental, with no dependence for existence of the pathogen upon tobacco.

Differences in resistance have been reported between tobacco varieties to both infection and ease of natural water-soaking which leads to infection. Heggestad (**1945**) studied varieties of tobacco with respect to what he called susceptibility and resistance to natural water-soaking and found that certain varieties water-soaked very readily and, if atomized with bacteria, developed severe wildfire, while other varieties water-soaked very slowly and, if atomized with bacteria, developed very little disease. He found these conditions to be inherited in hybrids between resistant and susceptible varieties and thought that resistance was probably controlled by multiple factors, although there was some suggestion of dominance of resistance. There was some indication that commercial varieties might be developed, by hybridization, that would carry resistance to water-soaking and therefore be less subject to wildfire.

Johnson et al. (**1924**) were unable to find resistance in any tobacco varieties tested, nor could they find resistance in the *Nicotiana* species tested. This was probably because of the method of inoculation used (wounding). Anderson (**1925**) tested 41 varieties of tobacco but found none resistant; but by the method of inoculation he used (sprinkling diluted culture on plants at night) he concluded that some species were resistant. He considered *N. rustica, N. repanda, N. nudicaulis* and *N. attenuata* highly resistant. At the present time *nudicaulis, rustica* and *attenuata* are considered susceptible. Some of the species, as *longiflora*, that Anderson considered susceptible are now considered highly resistant. Anderson crossed *N. tabacum* with *N. nudicaulis* and *N. alata* and found that the first generation hybrids were highly resistant, thus demonstrating that resistance is a dominant factor. As the hybrids were sterile, he made no further progress in breeding for resistance.

In Europe a test of many varieties of tobacco indicated that there were distinct differences in resistance of varieties from different localities (Schmidt, **1934**, **1935**), while Piescu (**1935–36**) claimed to have found complete resistance in

some varieties and high resistance in others. Schmidt (1934) also tested other species of *Nicotiana* and found that nine varieties of *N. rustica* were susceptible, while *N. viscosa* (probably *N. Langsdorfii* var. *longiflora*), *N. affinis* (*N. alata* var. *grandiflora*), *N. plumbaginifolia* and some other species were resistant. *N. Sanderae* segregated into susceptible and resistant varieties.

Clayton (1947, 1948) was unable to find resistance in numerous varieties of *N. tabacum* but found that *N. longiflora* carried a Mendelian dominant factor for what amounts to immunity, although the organisms multiply in the leaf tissue slowly but without developing symptoms (Diachun and Troutman, 1951). Other species, as *N. debneyi*, some plants of *N. bonariensis* Lehm., *N. plumbaginifolia* Vir., some plants of *N. alata* Link and Otto, and perhaps other species also show a high degree of resistance to wildfire (Diachun and Valleau, unpublished).

Crosses can be made between *N. tabacum* ♀ × *N. longiflora* ♂, but most of the seeds are hollow. A very few, however, are viable. The reciprocal cross is usually a failure, but when very young flowers of *N. longiflora* are emasculated and pollinated with *N. tabacum* an abundance of viable seed is obtained (C. T. Chu, unpublished). Clayton (1947) raised seedlings of hybrids between $4n$ plants of these two species and found them to be sterile, but finally a shoot developed from one plant that proved to be self-sterile but fertile when backcrossed with *N. tabacum*. From a *N. tabacum* backcross a pure breeding variety—TL 106—of the flue-cured type practically immune to wildfire was obtained. This variety, while fertile, is not completely so because many of the ovules never develop into seed but appear as a fine dust when seed is removed from dried pods. Breeding results indicate that the resistance factor in TL 106 is not combined with a *tabacum* chromosome. F_1 crosses of TL 106 with flue-cured varieties showed marked heterosis in the plant bed and the field and nearly all plants were resistant (Clayton, 1947).

Valleau (1948) separated a few viable seeds from the *N. tabacum* × *N. longiflora* cross, treated the seedlings, as they germinated, with colchicine and obtained four plants that were self-fertile and could be backcrossed with *N. tabacum*. From this cross, strains of burley and darkfired tobaccos have been developed, a few of which appear to breed nearly true for wildfire resistance, and many other strains that have varying percentages of resistant plants. The backcross parents used were resistant to mosaic, black root-rot and in some cases fusarium wilt, so that if pure breeding wildfire-resistant varieties are developed they will also be resistant to the other two or three diseases (Valleau, 1948). Clayton et al. (1951) reported the development of strains of burley homozygous for wildfire resistance. An interesting feature of these strains is the apparent linkage between a lower nicotine content than in the usual burley varieties with wildfire resistance. Nicotine ranging between 1.83 and 2.88 percent should be much more desirable than that of the commercial varieties which contained from 3.60 to 4.23 percent under the same conditions.

Schneider and Beach (1949) announced the development of two wildfire-resistant cigar filler varieties for use in Pennsylvania that appear to be as satisfactory as the established varieties. Progress is being made on the development of wildfire-resistant cigar types in Connecticut.

In breeding for resistance, selection of resistant plants is simple. Small seedlings a few days old may be inoculated with a suspension of bacteria in water, preferably in bright sunlight when stomata are open, or inoculations may be

made on older plants, as the plants are resistant at all stages of growth. Resistant plants usually remain entirely free from visible evidences of infection, while very young susceptible seedlings are quickly killed and older plants develop typical wildfire spots. As the resistance factor is dominant, backcrossing with the desirable parent may be done each generation in order to quickly obtain the desired type of plant. It is probably better to use the resistant plant as the pollen parent whenever possible because of the greater chance of developing stable hybrids. Pollen with abnormal chromosome make-up is less likely to survive and function than similarly constituted eggs. It is not yet known whether the *longiflora* chromosome carrying resistance will cross over with a *tabacum* chromosome and thus become a part of the *tabacum* genome, whether it will replace the corresponding *tabacum* chromosome, or whether the homozygous resistant varieties will be 48T + 2L.

Mosaic Resistance

Tobacco mosaic, a virus disease, has been a constant threat to tobacco crops perhaps as long as tobacco has been grown. The mystery as to the source of infection was partly cleared up with the discovery that much of the infection could be traced to the hands of workers which become contaminated by handling chewing or smoking tobacco made from infected plants. Another source of infection was found to be perennial weeds, while a third source is carry-over in the roots of tobacco that live through the winter, and a minor source is soil contamination (Valleau and Johnson, **1937**). Considering the multiplicity of sources of infection, the farmer who is troubled with this disease welcomes varieties of tobacco that are resistant.

Until recently all varieties of *N. tabacum* were considered to be susceptible to tobacco mosaic. Gutierrez (**1935**), in the Philippines, selected plants of Vizcaya and Baker Sumatra that showed the least injury from mosaic, crossed them, and from this cross selected strains showing less injury from mosaic than usually occurs, thus indicating that there were some differences in the degree of susceptibility.

Ambalema Type of Resistance. It was not until Nolla and Roque (**1933**) announced the discovery, in Colombia, of the variety Ambalema, resistant to tobacco mosaic, that there was any real promise of resistance in *N. tabacum*. Nolla (**1935**) showed that while Ambalema was resistant to tobacco mosaic it was not resistant to other kinds of viruses that attack tobacco (Nolla, **1935**; Valleau, **1935**). Nolla compared the virus concentration in Ambalema with that in Havana tobacco and showed that it was consistently lower. He also gave evidence that in Ambalema the concentration of virus decreases with the age of the plant. These results are open to criticism, as he did not indicate the age of the actual tissue tested for virus concentration. Valleau and Diachun (**1941**) showed through the use of the " pure white " strain of the mosaic virus, which bleached invaded tissues of a resistant burley derivative of Ambalema, that very few particles of the virus were released for long distance transfer to growing point leaves, but that when once established the virus gradually solidly invaded the surrounding tissue until the whole leaf might be occupied. It is entirely possible that an assay of virus concentration in the solidly invaded areas might compare favorably with that in a susceptible plant, whereas a sample including invaded and uninvaded tissue from a younger leaf might give much lower concentrations than more completely invaded tissue from a susceptible plant of the same age.

Clayton et al. (1938) and McKinney (1939) reported that other varieties of Colombian tobacco were more resistant to mosaic than Ambalema. As an example, T.I. 448A seemed to have slower development and slower spread of virus than Ambalema (McKinney, 1939). It should be kept in mind, however, that Ambalema, in the original collection made by Nolla and studied by the writer, contained plants ranging from those that showed no outward evidence of infection when inoculated with several strains of virus, including the bleaching strains, to plants showing distinct mosaic mottling with non-bleaching strains. These probably represent the three classes of resistance described by Clayton et al. (1938). It is to be expected, therefore, that different persons will obtain different results when studying Ambalema, depending upon the degree of resistance of the plants selected for study.

Mosaic resistance in Ambalema and in related varieties seems to be governed primarily by two sets of Mendelian recessives (49th Ann. Rep. Ky. Agr. Exp. Sta., 1936; Nolla, 1938; White, 1950) with perhaps modifying factors as pointed out by Clayton et al. (1938). This means, of course, that only one plant in 16 can be expected to be resistant, but in actual practice only an occasional plant out of a progeny of several hundred F_2 plants appears sufficiently resistant in the seedling stage to warrant saving for further backcrossing. This limits the possibility of selection for plant type, reliance being placed on backcrossing as a means of attaining the desired type of plant.

The announcement of a mosaic-resistant variety of tobacco encouraged plant breeders over the world to attempt the development of mosaic-resistant varieties of local types of tobacco. The use of Ambalema and related varieties as a source of mosaic resistance was stimulated by the announcement (Clayton and McKinney, 1941) that following field tests of glutinosa resistant and Ambalema resistant varieties " it does not seem that the glutinosa type of mosaic resistance has any practical value ". They concluded further that " tobacco varieties possessing Ambalema resistance will certainly be introduced into cultivation in the near future ".

Actually, after 15 years of breeding with Ambalema on many types of tobacco, the results have been disappointing, to say the least. In 1934, hybrids were made by the writer between a highly resistant strain of Ambalema and burley tobacco at the Kentucky Agricultural Experiment Station (47th Ann. Rep. Ky. Agr. Exp. Sta., 1934), and the following year dark air and fire cured tobacco were included. By 1937 it had been demonstrated (50th Ann. Rep. Ky. Agr. Exp. Sta., 1938) that highly mosaic-resistant varieties of burley could be produced in which the virus of white mosaic (bleaching) showed no signs of spread from the inoculated leaves in the majority of plants. Some of these strains proved to be of high quality and yield in 1938 and 1939 field trials (52nd Ann. Rep. Ky. Agr. Exp. Sta., 1939).

In 1940 nine of the mosaic-resistant burleys were tested with about 500 farmers. They were black root-rot-resistant as well as mosaic-resistant and were high yielding, but the plant type was not satisfactory and all of the strains had the undesirable habit of wilting severely on hot days following a period of rapid growth. Wilting was often so severe that the leaves failed to recover completely, leaving large scalded areas in two or three leaves. This history of the breeding work (54th Ann. Rep. Ky. Agr. Exp. Sta., 1941) with burley has been given because it seems to represent fairly well the results other plant breeders in this country, in China and in other parts of the world have had

with Ambalema hybrids (personal correspondence). While little has been published on this phase, the fact that few if any successful varieties have been introduced which carry the Ambalema resistance factors is perhaps significant. Anderson et al. (1940) reported on a cigar tobacco resistant to mosaic but the quality was not satisfactory. Alcaraz (1944) reported progress in the development of resistant varieties in Spain after 12 years of work. In Tennessee, breeding work has been conducted at least since 1940 (Sherbakoff, 1940) with the Ambalema type resistance. In 1947 Latham announced that D534A1 yielded more than Black Mammoth (fire-cured) and sold for the same, indicating that progress was being made; but the next year (Latham, 1948) it was announced that several of the strains appeared promising. Attempts to develop mosaic-resistant varieties of burley, flue-cured and cigar tobaccos have been in progress at Ottawa since 1937 with promising results (White, 1950). Continued backcrossing with selected varieties of each type of tobacco was resorted to. The resistant strains closely approached the backcross parent in plant type. Ambalema has been used as a source of mosaic resistance at most of the tobacco breeding stations of the world.

Breeding and selection work has been continued by the writer in an attempt to free the Ambalema derivatives of burley tobacco from the wilting habit. One strain has been isolated that is "stand-up" in character—that is, the leaves do not droop—and which for several years has shown no sign of wilting. It is possible, therefore, that satisfactory mosaic-resistant varieties of the Ambalema type will eventually be developed, but the process is slow and tedious and the plant types obtained from both burley and dark tobacco hybrids are unsatisfactory.

It is interesting to speculate as to the reason for the Colombian varieties being resistant to mosaic, while all other varieties are susceptible. Two facts suggest that the Colombian varieties had a different origin from other varieties; one is the resistance to mosaic, and the other the fact that the only tobacco known to have a high degree of resistance to Granville wilt is one of these mosaic-resistant varieties (Clayton and Smith, 1942). Tobacco is supposed to have originated from a cross between *Nicotiana tomentosa* and *N. sylvestris*, both of which are susceptible to mosaic (Goodspeed and Clausen, 1928). *Nicotiana tomentosiformis*, we have found, carries the same type of resistance to mosaic that is found in Ambalema. A cross between *N. tomentosiformis* and *N. sylvestris* with a substitution of the mosaic susceptible factor of *N. sylvestris* by the mosaic-resistant factor of *N. tomentosiformis* could result in a variety such as Ambalema with four recessive factors for mosaic resistance. A test of various collections of *N. tomentosiformis* for its reaction to *Bacterium solanacearum* might give further evidence on this theory. Kostoff (1936) is of the belief that the common tobacco varieties originated from a cross of *N. sylvestris* × *N. tomentosiformis;* but if so we would expect to find mosaic resistance of the Ambalema type more general, unless *N. tomentosiformis* has forms susceptible to mosaic.

In breeding for mosaic resistance with Ambalema and its derivatives, much of the testing work may be done in the greenhouse. If a cross between a resistant and a susceptible is made in the field, the F_1 may be grown in the greenhouse and the F_2 seed obtained in time to sow, inoculate the young seedlings with mosaic, and select the few that may result from several hundred plants that show virtually no effect from inoculation. These may be set in the field for

observation and further selections for resistance and plant type. Because of the fact that so few highly resistant plants appear, reliance must be placed largely on backcrossing to attain the desired type. The process of development of satisfactory varieties is therefore slow, as there appear to be highly undesirable plant characters associated with the resistance factors in the two pairs of chromosomes carrying resistance. Probably these will gradually be gotten rid of through crossing over.

Glutinosa Type of Resistance. *Nicotiana glutinosa* and some other species of *Nicotiana*, as *rustica, benthamiana, repanda, sanderae, maritima, undulata, velutina* and *gossei,* respond to inoculation with any strain of the tobacco mosaic virus by producing necrotic spots at the points of entrance of the virus. At a moderately low greenhouse temperature (60° F.) infection is localized; at higher temperatures (70° F. or above) the virus may spread into the veins and finally into the stalk, causing systemic necrosis. At a still higher temperature (97° F.) the virus may become systemic and cause mottling without necrosis (McKinney and Clayton, 1945).

The fact that *N. glutinosa* gives both the necrotic reaction and the mottle reaction, depending on temperature, proves that it carries the necrotic factor and a factor for susceptibility to mosaic but does not indicate whether or not the factors are identical. By crossing *N. glutinosa* with an Ambalema type mosaic-resistant burley, doubling the chromosome number by treating with colchicine, and raising seedlings it was demonstrated that *N. glutinosa* carried two distinct factors—the N factor for necrosis and an A factor for susceptibility to mosaic (Valleau, 1949).

In 1916 Allard stated that *N. glutinosa* (which he called *N. viscosum*) appeared to be immune to the ordinary form of mosaic disease affecting *N. tabacum.* Likewise the first generation plants of the cross *N. tabacum* × *N. glutinosa* appeared to be quite as immune as *N. glutinosa.* He noticed (1914) that these hybrids, like the male parent, are attacked by a very destructive rot at the points of injury if the mosaic virus is punctured into the stems. That he did not recognize this as a distinct kind of reaction to the virus is suggested by his statement regarding *N. rustica:* "Directly or indirectly as a result of the disease many affected plants are attacked by a progressive decay of the tissues, which sometimes involves the entire plant, killing it to the ground". If the rubbing method rather than the pricking method of inoculation had been used it is probable that the necrotic reaction would have been recognized much earlier.

Holmes (1929) first called attention to local lesions, both chlorotic and necrotic, as a means of measuring virus concentration. He stressed particularly the value of *N. glutinosa* because of the rapidity of development of spots following inoculation. He then proved by species crosses in *Nicotiana* and variety crosses in *Capsicum frutescens* L. and *Solanum melongena* L. that the localizing or necrotic factor in these three genera is a simple Mendelian dominant and that mottling is determined by an allelomorphic recessive (1934).

Kunkel (1934) found that several varieties of *Nicotiana tabacum,* when inoculated with the English tomato Aucuba mosaic, developed local necrotic lesions but usually failed to become systemically infected. Valleau (1935) studied many varieties and hybrids between varieties of tobacco and found that they could be divided into necrotic and mottling varieties when inoculated with aucuba and several strains of the virus collected in the United States. The necrotic factor was found to be dominant over mottling, and it usually caused

localization of the virus when in a homozygous condition, but in heterozygous plants the virus usually became systemic, resulting in a necrotic streak-like disease. Later it was shown that the necrotic spotting varieties reacted with necrosis to the plantago virus (Valleau and Johnson, 1943). The factor controlling the reaction was designated N′ to distinguish it from the N factor of *N. glutinosa*. Recently Weber (1950) studied what appears to be the same factor and designated it n^s because it seems to be recessive to the N factor in Nn^s plants. It is true that it is recessive to the N factor from *N. glutinosa,* but it is also true that the N′ or n^s factor is dominant over the n factor in *N. tabacum*. There is no indication that the N′ factor is of any value in mosaic control, but it is interesting that a factor similar to the N factor, with respect to certain virus strains, is present in many tobacco varieties.

Some assurance was given to plant breeders and pathologists that mosaic might be controlled by interspecific hybridization when the N factor from *N. rustica* was transferred to *N. paniculata* (Holmes, 1936).

Kostoff (1937) was also exploring the possibilities of using the necrotic factor in mosaic control. He found that three mottling type genes would predominate over the necrotic gene from *N. rustica*. Ternovsky and Khudyna (1938) attempted to produce mosaic-resistant tobaccos through the use of the *glutinosa-tabacum* amphidiploid developed by Ternovsky in 1932. Ternovsky (1938, 1945) reported that the N factor was dominant in F_1 and in the sesquidiploid with two genoms of *N. glutinosa* and one of *N. tabacum,* and one genom of *N. glutinosa* and two of *N. tabacum*.

At the same time Holmes (1938) reported that the N factor had been established in the variety Samsoun in a homozygous condition, giving further proof that tobacco varieties having the same reaction to mosaic virus as *N. glutinosa* could be developed. This work was made possible by geneticists who had already prepared tetraploid *glutinosa-tabacum* hybrids which bred true and could be backcrossed with *N. tabacum* (Clausen and Goodspeed, 1925). This new tetraploid species was called *N. digluta*.

In common with many other interspecific hybrids in *Nicotiana,* the cross between *N. glutinosa* and *N. tabacum* and between *N. digluta* and *N. tabacum* can best be made in one direction, in these crosses, using pollen of *N. tabacum*. This appears to be because the endosperm combinations 12g + 12g + 24t and 36d + 36d + 24t seem to function normally, whereas the combinations 24t + 24t + 12g and 24t + 24t + 36d fail to function and the embryo does not develop (Cooper and Brink, 1942). By repeated backcrossing on a series of generations of N plants the chromosome number is soon reduced from 72 of *digluta* to 48 or near 48 of tobacco, and after three or four backcrosses the type of plant used as the backcross parent is approached very closely but not exactly. For example, after nine backcrosses with Ky 16, homozygous resistant plants, although appearing nearly identical with Ky 16, yielded somewhat less, and the quality of the leaves on the upper portions of the plant averaged lower. Other varieties, as Ky 34, Ky 35 and Ky 57, which carry the N factor are high yielding.

Through the use of *N. digluta* developed by Ternovsky and sent to the writer by Dr. Goodspeed; a fifth backcross of Ky 16 on *digluta* prepared by Holmes; and Holmes NN Samsoun, many homozygous resistant strains of burley, dark fire-cured and one-sucker tobaccos were developed at the Kentucky Agricultural Experiment Station. During the several years before 1940, when the first NN variety of burley was

tested by farmers, the value of the NN factors as a means of controlling tobacco mosaic became clearly evident. It was a surprise, therefore, when the announcement was made in 1941 that "under tobacco producing conditions that prevail in this country, it does not seem that the glutinosa type of mosaic resistance has any practical value" (Clayton and McKinney, 1941). This statement was based on field tests in which presumably heavily inoculated N plants died from systemic necrosis. The fact was disregarded that in a tobacco field inoculation of any one plant is usually very light, and in a field of *glutinosa*-type resistant plants there would be no source of infection other than perennial weeds and the small amount of virus resulting from personally used smoking or chewing tobacco (Valleau, 1942). After more than ten years field experience with the glutinosa type of resistance, during which time many thousands of acres of mosaic-resistant tobacco have been grown in Kentucky, it can be stated that this type of resistance is completely satisfactory as a means of controlling all strains of the common tobacco mosaic virus tested, and the plantago virus.[2] Some of the Kentucky mosaic-resistant varieties of dark tobacco are being grown successfully in Chile, South America (Astorgo and Quintana, 1948).

Kostov and Georgieva (1944) continued work on mosaic resistance in Bulgaria. From the series of crosses *N. rustica* × *N. tabacum* × *N. digluta* × *N. tabacum* × *N. tabacum* a desirable variety homozygous for mosaic resistance and with 48 chromosomes was selected. This was named *N. tabacum* var. *virii.* It was used in crosses with other commercial varieties of *N. tabacum* in an attempt to convert them to mosaic-resistant varieties. They pointed out that better results would be obtained in backcrossing if the Nn parent were the pollen parent.

Goodspeed (1942) produced an amphidiploid of *N. glutinosa* × *N. silvestris* and by backcrossing it to tobacco produced a commercial type of tobacco possessing the mosaic resistance of *N. glutinosa.* Ternovsky (1941, 1945) developed varieties of tobacco resistant to both tobacco mosaic and powdery mildew and practically identical with Dubec, the backcross tobacco parent. Flue-cured tobacco varieties Vamoor 48 and 50 resistant to mosaic and black root-rot were developed at the Virginia Experiment Station (Henderson, 1949).

The question as to what happens to the *glutinosa* chromosomes when the necrotic spotting factor is incorporated in a mosaic-resistant tobacco variety is of interest not only in this case but in giving some insight as to what may be expected when attempts are made to incorporate genes from other species in *N. tabacum.*

Gerstel (1943) made a cytological study of Holmes Samsoun (HS) and, because the F_1 hybrids between HS and other *tabacum* varieties regularly exhibited an unassociated non-conjunctional pair of chromosomes, he concluded that mosaic resistance in HS had been achieved by substitution of the entire *glutinosa* chromosome for the corresponding *tabacum* chromosome. He demonstrated that one of the non-conjunctional chromosomes was responsible for mosaic resistance. He warned the plant breeder that it would be advantageous to use

[2] Recently specimens of a dark-fired mosaic-resistant tobacco (NN) were received which had a long black necrotic streak nearly an inch wide down the side of the plant. The pith also was necrotic. Inoculations from a leaf and the pith resulted in numerous necrotic spots on NN plants, indicating that the tobacco mosaic virus was responsible. The affected mosaic-resistant plants were in a field with susceptible varieties, and in topping and suckering the grower had evidently worked from susceptible mosaic-affected plants to resistant ones, resulting in heavy infection of the tender stem with necrosis of the stalk.

heterozygous (Nn) plants as pollen parents in transferring mosaic resistance to other *tabacum* varieties in order to avoid a change in chromosome number in some of the sibs to either 47 or 49.

Later Gerstel (1945*a*) identified the chromosome concerned in susceptibility and resistance as the H chromosome. This was done by crossing a series of monosomics of *Purpurea* (plants lacking one of the pair of each of the chromosomes) with HS. The cross (haplo-H Purpurea) × HS gave monosomic offspring with 23 pairs of chromosomes and one univalent, Hg, in the first meiotic metaphase of PMCs. Test crosses with other monosomics gave 22 pairs and three univalents. These were Hg, Ht and the chromosomes from HS which was lacking in the monosomic. From this cytologic and from other genetic evidence it was concluded that the H chromosome had been replaced by a *glutinosa* chromosome with which it did not conjugate.

In the opinion of the writer it is not at all certain that in Holmes Samsoun crossing over between the *tabacum* and the homologous *glutinosa* chromosome had not already taken place, combining enough of the *tabacum* H chromosome so that the new chromosome acted as a part of the *tabacum* genom even though it did not appear to conjugate with an Ht chromosome. This conclusion is drawn because, as Gerstel (1943) states, the HS plants appeared to be perfectly normal tobacco plants.

The writer found a great deal of variation in homozygous isolates from the fifth backcross generation of Ky 16 on *digluta* (Valleau, 1942), suggesting that in the different isolates different amounts of the *glutinosa* chromosome were present. Two strains bloomed low and were of an unusually light color. The plants were different from anything that the writer had seen in burley tobacco and had evidently derived some of these characters from the H chromosome of *N. glutinosa.* Other strains, however, were typical burley tobacco and evidently had lost the undesirable characters of *glutinosa.* It seems probable that if HS had two complete *glutinosa* chromosomes there would have been some indication in the appearance of the plants and they would not have been so similar to Samsoun. Another point which should have bearing on the question is the inheritance of the necrotic reaction. At some time during the process of backcrossing a point is reached when the N factor gives monohybrid ratios. This the writer has considered as evidence that crossing over had taken place and that reliance was no longer placed on a foreign chromosome that did not act as a member of the tobacco genome.

The writer now has on hand homozygous resistant strains derived by repeatedly backcrossing Ky 16 on Gerstel's 50-chromosome mosaic-resistant Purpurea (48t + 2g) and then isolating homozygous lines. These homozygous lines that seem to contain 48 *tabacum* chromosomes of Ky 16 plus 2 *glutinosa* chromosomes appear exactly like the low blooming, light colored homozygous segregates from the fifth backcross Ky 16-*digluta* hybrid and do not give monohybrid ratios if crossed.

Another reason for believing that HS did not contain a whole *glutinosa* chromosome is that in using it in the development of dark fired and dark air-cured mosaic-resistant varieties there was never any indication in the backcross generations or in the homozygous derived lines of undesirable *glutinosa* traits such as appeared in some of the early burley lines, and the *glutinosa* factor acted as though it were a part of the *tabacum* genome.

Kostoff (1948) was not convinced that the whole *glutinosa* chromosome had been transferred from *N. glutinosa.* He presented cytologic evidence that some

degree of conjugation between *tabacum* and *glutinosa* chromosomes in hybrids had been observed. It seemed unlikely to him that good quality tobacco would have resulted if two whole chromosomes had been transferred to *tabacum*.

Gerstel (1948) finally demonstrated to his satisfaction that transfer of mosaic resistance had taken place from the H chromosomes of *N. glutinosa* to *N. tabacum*. When mosaic-resistant burleys derived by backcrossing on HS and then selfing were crossed with non-resistant burley or Purpurea and the metaphase plates of PMCs examined it was found that the majority exhibited 24 pairs, while the remainder had an unassociated pair. This indicated that the N-bearing chromosome was at least similar enough to the Ht chromosome so that conjunction could occur. At the present time the N factor is so well established in the *tabacum* genome that there should be no difficulty in transferring mosaic resistance to any type of tobacco.

For the plant breeder who is contemplating developing NN strains of local varieties of tobacco, some suggestions may be in order. It is not necessary to use *N. digluta* as a source of the N factor, as it appears to be attached to a *tabacum* chromosome in several commercial varieties of tobacco. Because the factor is a Mendelian dominant, each generation may be backcrossed until the desired type is attained, which takes from three to five generations. In selecting the N plants, very young seedlings may be destroyed by systemic infection before the inoculated leaf can be removed, but if the plants are allowed to become established in thumb pots and the temperature is kept below 70° F., systemic necrosis usually does not occur. If it is desired to select N plants from the bed for field setting, all of the plants in a bed can be inoculated about three days before setting and then at pulling time only plants with necrotic spots need be pulled. There is not sufficient virus in the nn plants to contaminate the fingers and cause stem infection on the N plants, which would result in their death. In making inoculations in the field it is better to make them on a small area of the blade between large veins rather than on the midvein or larger veins. This decreases the chance of the virus becoming systemic by advancing down the midvein. The hands should be virus-free when handling the flower head in making crosses or bagging plants, as necrosis may develop which may kill the inflorescence. When searching for homozygous plants in a backcrossed line, about 20 plants should be bagged in the F_2 of the last backcross generation and the progeny tested individually. Usually 30 plants are tested, and if all give the necrotic reaction the strain can be considered to be homozygous. For some unknown reason, certain Nn strains do not give NN lines, even after several years of selfing.

Etch and Veinbanding Viruses

With the introduction into the United States, either during or following the second world war, of a strain of the green peach aphis that attacks tobacco, there is a possibility that aphis-transmitted viruses may become more of a factor than they have been in the past.

At present the etch virus has a rather limited distribution in tobacco-growing areas, being found occasionally in tobacco growing near old garden sites. The virus has been transferred from naturally infected *Physalis* sp. growing in these areas. Also it has been transmitted to *Solanum carolinense*, a very common weed in tobacco-growing areas (Johnson, 1930). It is probable that the virus will gradually become established in more and more solanaceous perennials and perhaps in plants of other families also (Holmes, 1946) and gradually become a menace to the tobacco crop.

Holmes has shown that *Nicotiana tomentosiformis* is resistant or immune to the virus, and this has been confirmed by the writer (62nd Ann. Rep., Ky. Agr. Exp. Sta., 1949) who found also that this species is a symptomless carrier of veinbanding, another aphis-transmitted virus. Thus a source of resistance to the etch and veinbanding viruses is available. The writer has crossed *N. tomentosiformis* with two varieties of burley. Viable seed was obtained when *tomentosiformis* pollen was used, but seed from the reciprocal cross did not germinate. The hybrids were nearly completely sterile, but a few seeds set in an occasional pod when the hybrid was pollinated with tobacco pollen.

The F_1 hybrid was susceptible to the etch virus, indicating that resistance is a recessive. The work has not progressed far enough to know whether it will be possible to transfer the resistance factor to tobacco. However, considering the high degree of sterility and the fact that resistance is recessive, the chances of success are rather small.

Streak

Streak is a virus disease of tobacco that is becoming increasingly common, particularly in the more northern tobacco-growing areas of North America (Berkeley, 1943; Fulton, 1948; Valleau, 1940). The virus or one closely related to it is prevalent in Colorado, Idaho and Wyoming where it causes the red node disease of bean (Thomas and Zaumeyer, 1950). It is also a destructive disease of tobacco in China (T. C. Chu, correspondence) and in Brazil (A. S. Costa, correspondence). It is evidently insect-transmitted, but the vector is not known. The virus has a wide experimental host range and is found in nature in plant families distantly related to the Solanaceae (Valleau, 1940; Berkeley and Phillips, 1943; Fulton, 1948). If the virus is gradually becoming established in the wild vegetation of the tobacco-growing areas of North America, it can eventually become a serious and destructive disease over a wide area, as it is now in restricted areas. Probably the only means of control will be through developing resistant varieties if this proves feasible.

Diachun and Valleau tested 460 accessions of *N. tabacum* and found them all to be susceptible to the virus (60th Ann. Rep. Ky. Agr. Exp. Sta., 1947). They also inoculated 35 species and found that 33 were equally as or more susceptible than *N. tabacum*. Two species, *N. glauca* and *N. gosseii*, showed a high degree of resistance (Diachun and Valleau, 1947).

The hybrid *N. gosseii* × Ky 55 was easily made, and the seed germinated readily. However, the seedlings gradually turned yellow and died, apparently the result of a non-pathogenic necrosis of the roots and crown. Attempts to make the reciprocal cross, using tobacco as the female parent, were not successful. When a tetraploid *N. tabacum* var. *purpurea* was pollinated with *N. gosseii* pollen, viable seed were produced, but no seed developed from the reciprocal. The viable seed produced seedlings that grew better than the *N. gosseii* × *N. tabacum* seedlings, but eventually all of the seedlings but one died. This one developed normally and set a few seeds when pollinated with Ky 56, but the resulting seedlings developed systemic streak. It is possible that further progress could be made through the use of this hybrid, but resistance appears to be governed by a recessive factor, and this with sterility and root breakdown makes progress difficult and uncertain.

The amphidiploid *Nicotiana tabacum* var. Ky 55 × *N. glauca* was prepared by treating the hybrid seed with colchicine as the seedlings germinated. This hybrid grew readily and, when inoculated with the streak virus, developed necrotic spots, but systemic infection developed

more slowly than in tobacco. Resistance of *N. glauca* is at least partially recessive. Backcrossing with tobacco resulted in some good seed, but the plants were all susceptible to streak. The second backcross resulted in very few seeds, and the plants were again susceptible. With the high degree of sterility and no way of selecting plants carrying the resistance factor, this line of breeding does not offer much promise.

Nematodes

There are at least two major root diseases of tobacco caused by nematodes—root knot caused by *Meloidogyne incognita* (Kofoid and White) Chitwood (formerly *Heterodera marioni* (Cornu) Goodey (Chitwood, 1949)) and brown root-rot caused by species of *Pratylenchus* and perhaps, in part, by other parasitic nematodes (Valleau and Johnson, 1947). The most abundant species in the roots of tobacco and other crop plants has commonly been called *Pratylenchus pratensis*, but according to Dr. Steiner this should not be done, for there are at least three closely related species concerned (Graham, 1948; Tobacco Disease Council, 1949).

In Ontario, Canada, the meadow nematode involved, according to Steiner, is close to one called the broad-headed nematode that is also present in Chatham, Virginia, and Connecticut, while another form is present at Florence, South Carolina (Koch and Stover, 1950; Anderson, 1948). In the Ontario specimens Steiner also found *Tylenchorhynchus claytoni*, a form " continuously observed on dwarfed plants " and thought to be very poisonous to the plant host (Koch and Stover, 1950). Koch and Berkeley (1950) consider that brown root-rot in Ontario is primarily due to *Anguillulina pratensis*. Although there is a possibility that the species of meadow nematode present in Harrow, Ontario, and Lexington, Kentucky, may be different, yet varieties of burley tobacco that appear to be most resistant at Lexington are reported as highly resistant at Harrow, and Harrow Velvet, a variety very susceptible in Ontario, is one of the most susceptible at Lexington. The contrasts between resistant and susceptible varieties at Lexington are not as great as at Harrow (Valleau and Johnson, 1947; Koch and Stover, 1950). The greater contrast at Harrow may be found to be the result of a higher degree of infection following transplanting to the sandy loam soil at Harrow than to the " heavier " soil at Lexington, thus giving a greater opportunity for contrast.

In Florida Kincaid has reported a somewhat different set of symptoms on the roots of nematode-infested tobacco, which he calls " coarse root " to distinguish it from brown root-rot. Recently Steiner, in personal correspondence, has stated that the culprit is probably the nematode *Trichodorus* sp. which attacks just the root tips but does not enter the root. This nematode he believes to be a hitherto overlooked factor in the decline of many crops.

With respect to the root knot nematodes affecting tobacco there is confusion. Christie (1946) showed that there are several root knot nematode populations in this country that can be distinguished from one another by their rate of development within the roots of several host plants. One population might make practically no growth following penetration of a root, while another population in the same kind of root might develop normally and produce eggs. Populations with all degrees between these extremes could be found. Chitwood (1949) studied root knot nematodes from several sources and pointed out that a group which he placed in the genus *Meloidogyne* Goeldi differed from *Heterodera* in that the former did not form cysts such as are produced by

the latter. Within the genus *Meloidogyne* he recognized four species and one variety, all of which are found in the United States. *M. incognita* (Koifoid and White) Chitwood appears to be the native nematode in the southern States and is probably the one most common in tobacco (Chitwood, 1949; Sasser, 1951). According to Chitwood there seem to be a number of varieties of this species differing in the mean position of dorsal gland orifice and number of distinct post-labial annules in the males. There is also variation in the progeny from the egg mass of a single female. It is still to be determined whether the other species attack tobacco and how many strains of *M. incognita* differing in parasitism there are. Until this information is available there can be no assurance that resistant varieties or species will prove to be permanently resistant to all strains of *incognita* and all species of *Meloidogyne*.

In a search for nematode resistance, Clayton (1940) studied tobacco varieties and found that it was possible, by repeated selfing, to establish homozygous lines with a marked degree of nematode resistance. In 1947 he found that a Central American variety designated T.I. 706 was highly resistant to the nematodes which cause both root knot and brown root-rot (Clayton, 1947).

T.I. 706 has been crossed with flue-cured varieties, and the strains resulting from the cross have been tested at the McCullers Station, North Carolina. Strains with a high degree of resistance to both the root knot and meadow nematode and having considerable resemblance to flue-cured tobacco have been obtained. The best type plants had only moderate resistance, but by crossing two strains of different degrees of resistance a strain with yielding capacity and quality approaching the better standard varieties has been obtained (Nusbaum and Todd, 1949). According to Clayton (1947), the roots of T.I. 706 are invaded by the root knot nematodes but they gradually starve. This is in keeping with the findings of Barrows (1939) who believed that resistance was entirely within the plant, resulting either in death or slow starvation of the nematode. The type of resistance with respect to meadow nematodes is not so certain. Graham (1948) is of the opinion that there is a correlation between vigor of growth and resistance to meadow nematodes. Resistance may be in part the ability to produce new roots rapidly. Stover (1951) found no significant difference in the meadow nematode population per gram of roots of a resistant and susceptible variety of burley, and Valleau and Johnson, in their studies, could see no appreciable difference in the populations of several resistant varieties and susceptible ones (unpublished).

T. E. Smith informed the writer that he has seen T.I. 706 growing vigorously in soil infested with both nematodes late in the fall when the roots of other varieties were dead. In the burley, dark air- and fire-cured and cigar tobacco areas, where root knot nematodes are not a factor, the degree of resistance found in such a variety as Green Briar (Koch and Stover, 1950) should prove of great advantage, as it appeared to yield about as well in untreated ground as the susceptible variety Harrow Velvet in soil treated with the most effective chemical. Other burley varieties that show considerable resistance are Kelley and Judy's Pride (Koch and Berkeley, 1950). Of the flue-cured varieties, White Mammoth, Bonanza, White Stem Orinoco and Duquesne appear to be more resistant in Ontario than other varieties (Koch and Haslam, 1940).

Clayton (1940) tested species of *Nicotiana* and found that some were highly susceptible, while others, as *longiflora, megalosiphon, repanda, nudicaulis* and *nesophila,* were highly resistant or im-

mune. Christie (1946) tested *N. megalosiphon* with one population of root knot nematodes and found that while it developed knots only about one female in fifty reached maturity and produced a few eggs. *N. plumbaginifolia* also proved to be a poor host, as only a few parasites ever reached the molting stage. According to Christie (1946), Clayton has tested *N. plumbaginifolia* in several locations in the southeastern States but has never observed appreciable galling of the roots.

Kincaid (1949) made crosses between shade tobacco and *N. repanda* and *N. plumbaginifolia*, both resistant to root knot, and from these be obtained fertile hybrids, some of which were highly resistant to root knot but of little value as tobacco.

Broomrape

Broomrape of tobacco, usually caused by *Orobanche ramosa* L., is a destructive disease of tobacco in southeastern Europe, North Africa, India and to a less degree in other tobacco-growing areas. In Kentucky it is destructive in an occasional field, but growers know these fields and avoid them. It was evidently introduced with hemp. At least five other species are said to occur on tobacco. One of these, *Aphyllon ludovicianum* Gray, is sometimes found on tobacco growing in low land recently cleared, but is not the most common species in Kentucky.

Ternovsky (1934) studied tobacco varieties and *Nicotiana* spp. in the hope of finding resistant material. One year some varieties, of 34 studied, appeared to show resistance, while others were heavily infected, but the next year, with heavier watering, there was no indication of resistance, and he concluded that in *N. tabacum* there are no unreceptive varieties. Nineteen species of the section Petunioides, including 30 collections, were studied. They were all susceptible except *N. multivalvis*, and it apparently matured too early for *Orobanche* to develop on it. Twenty-two collections, including nine species in the section Rustica, were less affected than the Petunioides, but all plants of *N. glauca* were affected. From these studies there seemed little hope of control through resistant varieties.

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Utilization Abstract

White-Potato Starch. About 98% of the starch produced in the United States is made from corn, the remainder mostly from cull and surplus white potatoes. " The maximum production of the potato-starch industry is believed to be approximately 89 million pounds, attained in the 1946–47 season, when Maine produced an estimated 44 million pounds and Idaho 45 million pounds. The average production in recent years has been somewhat below that record ".

The white-potato starch industry in the United States began in Antrim, N. H., in 1831. By 1880 more than 150 factories were operating in Maine, New Hampshire, Vermont, Michigan, Wisconsin, Ohio and Minnesota. Although the per acre yields of starch from corn and potatoes are comparable, various economic factors have long made it more profitable to produce starch from corn, and today there are only 20 potato-starch factories in Maine and six in Idaho with a total combined potential production of about 100 million pounds per year.

" Potato starch is used in industry in about the following percentages: textiles, 30; foods, 20; paper, 20; dextrins, 15; confectionery, 5; and miscellaneous, 10 ".

The principal use is in sizing cotton warps, secondarily for sizing spun rayon and worsted warps. " Potato starch is outstanding in the strength it imparts to paper in beater sizing. Potato dextrins give relatively flexible films, which resist checking and remoisten readily ". (R. H. Treadway and W. W. Howerton, *U. S. Dept. Agr., Yearbook 1950–1951*).

BOOK REVIEWS

Crops in Peace and War—The Yearbook of Agriculture 1950–1951. More than 225 contributing authors. xviii + 942 pages. U. S. Department of Agriculture. Obtainable from Superintendent of Documents, Washington 25, D. C. $2.50.

For nearly 100 years the Yearbooks and Annual Reports of the U. S. Department of Agriculture were devoted to giving farmers information on how to produce more and better crops, and in recent years these Yearbooks have been devoted each year to a particular broad topic, with all articles in them bearing on that topic. Each of these books has dealt more or less with economic botany in its broadest aspects, but leaning more toward agriculture, soil science, forestry or pomology. The latest edition is concerned essentially with the work of the three Regional Laboratories of the Department, which in turn are concerned primarily with the utilization of plant products, and for this reason it should be of particular interest to readers of ECONOMIC BOTANY. Excellent reading and a wealth of information are offered on a great variety of subjects in its nearly 1,000 pages, and anyone interested in the modern uses of plants, particularly in the products derived from them, can ill afford to overlook this volume. Some of these articles are abstracted in this issue of ECONOMIC BOTANY, and others may be in subsequent issues.

Farming and Gardening in the Bible. Alastair I. MacKay. 280 pages. Rodale Press. 1951. $3.

No other book in all of literature has been the object of so much conflicting interpretation as has the Bible, and the plant life mentioned in that great Book has not escaped differences of interpretation any more than have the doctrines taught in it. The translators of the Scriptures were not botanists, and even if they had been, sufficient accurate information very likely would not have been available to them for correct identification of the plants mentioned in the Book with those of today. It is for this reason that the famous Swedish botanist, Celsius, for instance, who studied Bible plants in the XVIIth and XVIIIth centuries, gave 18 interpretations to what is referred to as hyssop, and that modern research has done little to clarify the problem. Other plant names in the original Greek and Hebrew have similarly caused disagreement among modern authorities, and different names, in some cases, have been assigned to the same plants in the King James and the Revised Versions of the Bible.

The situation is well brought out in this, the latest of many writings on Scriptural plants, wherein the author quotes abundantly from the Bible and then discusses in a continuous readable fashion the many plants mentioned. Gardens in general, herbs, trees of the forest, fruit and nut trees, the vine, vegetables, field crops, and perfumes, spices and ointments, all have their own chapters, in addition to a few others on plant materials and animal husbandry. Lest it be thought from the foregoing comment that we today do not know precisely what any of the plants mentioned in the Bible really were, attention may be called to the following few of those concerning which there is no question.

The cedars of Lebanon that built Solomon's temple, a huge treasure house and a palace for Pharaoh's daughter, one of Solomon's wives, were mighty trees represented today by only a few surviving members known by the same name, trees which today stand as remnants of the great forests of Hiram, King of Tyre. To build those structures probably called for the greatest instance of plant utilization in the ancient world, for, we have reason to believe, a timber crew of 100,000 workers labored in the forests about 25 years to cut the trees and transport them by floats to Joppa, port of Jerusalem.

Figs, dates, olives and pomegranates were the fruits we know by those names today, and the vine, of course, was the grape. The cereal grains of the Bible are barley, wheat, rye, millet, spelt, fitches and pulse, but all are referred to as " corn ", and on this point

the author has the following to say: " Corn provided an easy generalization for the Bible translators, but in the original tongue there is no such unanimity. The Old Testament gives seven distinct words which in the English translation are sometimes called corn but are in other passages varied into mixed produce, wheat, barn, threshing floor, field, stalk, victuals, grown up and son, to mention but a few of these alternates. The New Testament Greek words appear as corn in some texts, with variants elsewhere. When we investigate classified varieties such as ground corn, parched corn, beaten corn, standing corn, old corn, ears of corn and so on, we run into a very involved etymology ".

The papyrus reed that flourished in the shallow waters of the Nile is well known today throughout the world in tropical gardens, and in ancient times its roots were used for handles, utensils and fuel; the pliant stems were woven into baskets, mats, sails, ropes and sandals; and the pith was eaten, both raw and cooked. Most famous of its uses, however, was in the manufacture of paper, and on this score, Commander MacKay (the author is a retired member of the Royal Canadian Navy) has the following to say:

" Papyrus paper was prepared by cutting the reeds into thin longitudinal slices, which were then trimmed and laid side by side to the required width, and overlaid by short transverse strips. It is not known whether an adhesive was used, but the sheets were soaked in Nile water until they blended together. They were then pounded and smoothed, and sun-dried. The better varieties were further rubbed to the required degree of thinness and even texture. Depending on the length of the manuscript, additional sheets were appended lengthwise to the bottom of the preceding ones, and attached with paste. When completed, the long document was rolled up loosely, the best quality papyrus forming the outer part of the roll, thus protecting the inferior inner sheets ".

Distribution of British Pharmacopoeidal Drug Plants and Their Substitutes Growing in India. S. L. Nayar and I. C. Chopra. 56 pages. Coun. Sci. & Ind. Res., New Delhi, India. Rs. 1/4/–.

This pamphlet is a list of 100 pharmaceutical plants in the British Pharmacopoeia, regardless of where they grow wild or are cultivated, and of 21 Indian plants suitable as substitutes for those which are not found in India. The listing is alphabetically arranged, from *Abies sibirica* to *Zingiber officinale*, and for each species there are notes on uses, distribution and vernacular names.

Seaweeds and Their Uses. V. J. Chapman. xvi + 287 pages; illus. Methuen & Co., London, England; British Book Centre, New York, N. Y. $6.25.

Seaweeds have long served man in a variety of ways, and it is very gratifying to find that the literature on this utilization, heretofore confined almost exclusively to scientific journals, has been admirably correlated and presented in this well-illustrated and attractively written book. Professor Chapman has contributed to Economic Botany in connection with the survey made some years ago of the seaweed resources in the coastal waters of Great Britain, and it is therefore particularly pleasing to call attention to this very worthy volume.

Seaweeds of one sort or another and in various parts of the world have been used as commercial sources of iodine, potash and soda; of the extensively used culture medium agar which has numerous other outlets also; of food for beast and man; of medicine; and most recently of alginic acid which is finding a variety of uses from that of boiler-water compounds to the manufacture of synthetic fibers. In the eighteenth century European manufacture of soap, glassware and alum was dependent to a great degree upon the brown algae of neighboring waters for soda and potash, and until the exploitation of Chile saltpeter they were the principal source of iodine. Today the colloidal contents of seaweeds are extracted at several places in the United States and are used in a great variety of ways, one of the foremost of which is as a stabilizer in foods, particularly chocolate beverages where precipitation of the chocolate must be prevented.

The particular seaweeds used, the history of the many uses, the processes involved in those uses and the prospects for further development are among the many aspects discussed in this excellent study of one of the world's great and as yet relatively unexploited self-perpetuating sources of raw material.